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WALCOTT'S LOWER CAMBRIAN OLENELLID TRILOBITE COLLECTION 61K, MOUNT ROBSON AREA, CANADIAN ROCKY MOUNTAINS

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WALCOTT'S LOWER CAMBRIAN OLENELLID TRILOBITE COLLECTION 61K, MOUNT ROBSON AREA, CANADIAN ROCKY MOUNTAINS

W.H. Fritz

1992

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PREFACE

Charles D. Walcott, third Director of the United States Geological Survey and later Secretary of the Smithsonian Institution, had a profound effect on the knowledge of the Cambrian in Canada. As an active administrator and field oriented scientist, he knew the importance of studying promising outcrops. New names for Canadian fossils, formations, and mountains abound in his publications, along with liberal photographic accounts of his subjects.

This paper is an expansion of Walcott's project of describing a Lower Cambrian "subfauna" from the Mount Robson area — a project that he himself admitted was incomplete. Although Walcott's initial and only paper on the project was brief and written in haste, it contained clues that his trilobite collection comprised exquisite undescribed material. Having confirmed this suspicion, W.H. Fritz was able to expand Walcott's systematic descriptions and place the entire collection in a new biostratigraphic framework. In this paper, Fritz has demonstrated that Walcott's fossils came from two zones, and, like Walcott, Fritz has left clues about an unfinished area of research. In documenting an abrupt faunal change at the zone boundary, and illustrating a tantalizing plasticity in the evolution of the overlying trilobites, Fritz has brought an unexplained evolutionary event into focus.

Elkanah A. Babcock
Assistant Deputy Minister
Geological Survey of Canada

PRÉFACE

Charles D. Walcott, troisième directeur de la United States Geological Survey et plus tard secrétaire du Smithsonian Institution, a participé à accroître les connaissances du Cambrien au Canada. Comme administrateur actif et scientifique axé sur les travaux de terrain, il connaissait l'importance de consacrer une partie de son temps à la recherche d'affleurements prometteurs. Ses publications regorgent de nouvelles appellations de fossiles, de formations et de montagnes du Canada ainsi que de nombreuses photographies illustrant ses sujets.

Le présent document est un prolongement du projet de Walcott décrivant une "sous-faune" du Cambrien inférieur de la région du mont Robson — projet qu'il considérait lui-même incomplet. Même si le premier et seul document de Walcott sur le projet était bref et écrit à la hâte, il contenait des indices révélant que sa collection de trilobites contenait du matériel précieux non décrit. Ayant confirmé ce fait, W. H. Fritz a été en mesure d'accroître les descriptions systématiques et de placer la collection entière dans un nouveau cadre biostratigraphique. Dans le présent document, Fritz montre que les fossiles de Walcott proviennent de deux zones et, comme Walcott, Fritz a laissé des indices indiquant un domaine de recherche non complété. En enrichissant un changement faunique abrupt à la limite de la zone et en illustrant une plasticité tentante de l'évolution des trilobites sus-jacents, Fritz a mis en lumière un événement inexpliqué de l'évolution.

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WALCOTT'S LOWER CAMBRIAN OLENELLID TRILOBITE COLLECTION 61K, MOUNT ROBSON AREA, CANADIAN ROCKY MOUNTAINS

Abstract

In 1913 Walcott described well preserved olenellid trilobites from the Mount Robson area that "make up a subfauna in the upper portion of the Lower Cambrian that has not been found elsewhere." Recent field studies indicate the "unique" 61k collection came from a glacial moraine containing a mixture of fossils from the upper *Nevadella* Zone and lower *Bonnia–Olenellus* Zone. The source horizons for most of the 61k taxa were found in nearby sections, permitting an enlarged description of the fossils and a presentation of their ranges. Below the productive 61k source horizons are (in ascending order) *Nevadia weeksi* Walcott, *Nevadia parvoconica* sp. nov., and *Nevadella mountjoyi* sp. nov. First in the source horizons is *Nevadella eucharis* (Walcott) followed by *Nevadella perfecta* (Walcott). Above *N. perfecta* is a narrow (0.3 m) interval containing the boundary between the *Nevadella* and *Bonnia–Olenellus* zones. Found above the boundary interval is *Mummaspis occidens* (Walcott) gen. nov., followed by *Olenellus truemani* Walcott, *Laudonia bispinata* Harrington, *Olenellus truncatooculatus* sp. nov., and *Mummaspis oblisooculatus* gen. et sp. nov. *Olenellus muralensis* sp. nov. was not found in outcrop, but is known to coexist with *O. truncatooculatus* on some 61k slabs. It is presently only a guess that *Laudonia amputata* sp. nov. came from the productive interval. It was not found in outcrop and is not associated with other taxa on 61k slabs. *Gabriellus lanceatus* gen. et sp. nov. occurs in the medial *Bonnia–Olenellus* Zone, well above the main producing horizons.

Numerous locations in the North American Cordillera can be correlated with the beds containing the 61k taxa. The abrupt faunal change at the boundary between the *Nevadella* and *Bonnia–Olenellus* zones is briefly discussed.

Résumé

En 1913, Walcott a décrit des trilobites olenellidés bien conservés provenant de la région du mont Robson et constituant "dans la partie supérieure du Cambrien inférieur une sous-faune qui n'a pas été trouvée ailleurs". De récentes études sur le terrain indiquent que l'exceptionnelle collection de 61k provenait d'une moraine glaciaire contenant un mélange de fossiles de la partie supérieure de la zone à *Nevadella* et de la partie inférieure de la zone à *Bonnia–Olenellus*. Les horizons d'origine de la plupart des taxons de 61k ont été trouvés dans des coupes adjacentes, permettant une description élargie des fossiles et une présentation de leurs intervalles. Au-dessous des horizons d'origine de 61k productifs, on observe (par ordre ascendant) *Nevadia weeksi* Walcott, *Nevadia parvoconica* sp. nov. et *Nevadella mountjoyi* sp. nov. Dans les horizons d'origine, on trouve d'abord *Nevadella eucharis* (Walcott) suivi de *Nevadella perfecta* (Walcott). Au-dessus de *N. perfecta* on distingue un mince intervalle (0,3 m) contenant la limite entre les zones à *Nevadella* et à *Bonnia–Olenellus*. Au-dessus de l'intervalle limite reposent *Mummaspis occidens* (Walcott) gen. nov. suivi de *Olenellus truemani* Walcott, *Laudonia bispinata* Harrington, *Olenellus truncatooculatus* sp. nov. et *Mummaspis oblisooculatus* gen. et sp. nov. *Olenellus muralensis* sp. nov. était absent dans l'affleurement, mais il coexistait dans certaines plaquettes de 61k. Le fait que *Laudonia amputata* sp. nov. provienne de l'intervalle productif n'est encore qu'une supposition. Il était absent de l'affleurement et il n'est pas associé à d'autres taxons des plaquettes de 61k. *Gabriellus ianceatus* gen. et sp. nov. est présent dans la zone à *Bonnia–Olenellus* médiane, bien au-dessus des principaux horizons productifs.

De nombreux sites dans la cordillère nord-américaine peuvent être corrélés avec les couches contenant les taxons de 61k. Le changement faunique abrupt observé à la limite entre les zones à *Nevadella* et à *Bonnia–Olenellus* est brièvement traité.

Summary

Walcott's brief publication in 1913 on the fauna from locality 61k in the Mount Robson area has proven difficult to reconcile within a geological context. The stratigraphic position of the fauna was challenged by L.D. Burling, who assigned the fauna to an older formation. An older age was also suggested by C. Lochman in a comparison of one of her Mexican species with one of Walcott's described species, and also by her comparison of a second Mexican species that she had seen in an undescribed portion of Walcott's material from locality 61k. H.J. Harrington, who was probably unaware of the collection from locality 61k, made an initial description of one of the genera, using a single cephalon from the type area that had been provided by a later collector. More material from locality 61k was described by R.V. Best in a thesis that remained unpublished, and contained no helpful biostratigraphic data. A stratigraphic study by W.H. Fritz and E. Mountjoy in the type area showed that the collection from locality 61k came from two zones.

Detailed biostratigraphic data from the Fritz and Mountjoy study are presented here for the first time, and have been combined with data from the 61k material to produce a trilobite range chart. The chart shows that most of the 61k material came from the middle member of the Mural Formation. The fossil bearing beds are located both below and above the boundary between the *Nevadella* Zone and the *Bonnia–Olenellus* Zone. This general position for the 61k collection had been implied in Burling's work, but had been masked by his belief that the species ranges overlapped and that the collection represented part of a single fauna.

Trilobites from below the boundary were found to have a restricted diversity; those above are markedly different and exhibit diverse forms. The same abrupt faunal change at the boundary between the *Nevadella* Zone and the *Bonnia–Olenellus* Zone is noted in correlations of the strata at locality 61k to six areas between the Yukon Territory and Mexico.

Data are too sparse to explain the abrupt change at the above mentioned boundary, but two tentative interpretations are offered. The first is that there is an unrecognized regional disconformity at the boundary. The second incorporates the idea of a disconformity with the possibility that the actual boundary was a biomere boundary that was subsequently erased by erosion. If this were the case, it is suggested that erosion erased the initial biomere fauna, which would have had a minimal number of species due to shock after the biomere event. The resulting disconformity marking the local base of the *Bonnia–Olenellus* Zone would then have been overlain by a fauna representing the second phase of biomere evolution, which is rapid faunal diversification in response to a new environment.

In ascending stratigraphic order, trilobites described from below the zonal boundary are *Nevadia weeksi* Walcott, *N. parvoconica* sp. nov., *Nevadella mountjoyi* sp. nov., *N. eucharis* (Walcott) and *N. perfecta* (Walcott). Those from above the boundary are *Mummaspis occidens* (Walcott) gen. nov., *Olenellus truemani* Walcott, *Laudonia bispinata* Harrington, *Olenellus truncatooculatus* sp. nov., *Mummaspis oblisooculatus* gen. et sp. nov. *Olenellus muralensis* sp. nov. coexists with *O. truncatooculatus* on float blocks, and therefore occurs low in the *Bonnia–Olenellus* Zone. *Laudonia amputata* sp. nov. came from an unknown interval, but probably not far above the boundary. *Gabriellus lanceatus* gen. et sp. nov. is from well above the boundary, where it was found in the lower part of the medial *Bonnia–Olenellus* Zone.

Sommaire

Le court document publié en 1913 par Walcott sur la faune de la localité 6lk dans la région du mont Robson s'est avéré difficile à concilier avec le contexte géologique. La position stratigraphique de la faune a été mise en doute par L.D. Burling qui a attribué la faune à une formation plus ancienne. Un âge plus ancien a été également proposé par C. Lochman dans une comparaison de l'une de ses espèces mexicaines avec l'une des espèces décrites par Walcott ainsi que dans une comparaison d'une autre espèce mexicaine qu'elle avait observée dans une partie non décrite des fossiles de Walcott provenant de la localité 6lk. H.J. Harrington, qui n'était probablement pas au courant de la collection provenant de la localité 6lk, a décrit l'un des genres en utilisant un céphalon unique de la zone type tiré d'une collection ultérieure. D'autres fossiles de la localité 6lk ont été décrits par R.V. Best dans un thèse non publiée qui ne contenait aucune donnée biostratigraphique utile. Un étude stratigraphique faite par W.H. Fritz et E. Mountjoy dans la zone type indique que la collection de la localité 6lk provient de deux zones.

Les données biostratigraphiques détaillées recueillies par Fritz et Mountjoy sont présentées ici pour la première fois. Elles sont combinées aux données sur les fossiles de 6lk pour produire un tableau d'intervalle des trilobites. Le tableau montre que la plupart des fossiles de 6lk provenaient du membre intermédiaire de la formation de Mural. Les couches fossilifères sont situées au-dessous et au-dessus de la limite entre la zone à *Nevadella* et la Zone à *Bonnia–Olenellus*. Burling avait laissé sous-entendre cette position générale dans ses travaux, mais comme il croyait que les intervalles d'espèces se chevauchaient et que la collection constituait une partie d'une seule faune, cette observation est passée inaperçue.

Les trilobites situés au-dessous de la limite présentaient une diversité restreinte, et ceux situés au-dessus, des différences marquées et des formes diverses. Le même changement faunique abrupt à la limite entre la zone à *Nevadella* et la zone à *Bonnia–Olenellus* est relevé dans les corrélations des couches de la localité 6lk avec sept zones situées entre le Yukon et le Mexique.

Les données sont trop éparses pour expliquer le changement abrupt à la limite susmentionnée, mais deux interprétations possibles sont données. La première est qu'il existerait une discordance régionale non identifiée à la limite. La seconde est qu'il y aurait un discordance mais que la limite réelle serait une unité limite biostratigraphique qui aurait été érodée. Si tel est le cas, l'érosion aurait effacé la faune initiale de l'unité limite qui contenait un nombre minimal d'espèces après le choc causé par l'événement lié à l'unité limite biostratigraphique. La discordance résultante marquant la base locale de la zone à *Bonnia–Olenellus* aurait été sous-jacente à une faune représentant la seconde phase de l'évolution de l'unité limite, qui correspond à une rapide diversification de la faune par suite d'un changement de milieu.

Par ordre stratigraphique ascendant, les trilobites décrits dans la partie située au-dessous de la limite zonale sont *Nevadia weeksi* Walcott, *N. parvoconica* sp. nov., *Nevadella mountjoyi* sp. nov., *N. eucharis* (Walcott) et *N. perfecta* (Walcott). Les trilobites observés au-dessus de la limite sont *Mummaspis occidens* (Walcott) gen. nov., *Olenellus truemani* Walcott, *Laudonia bispinata* Harrington, *Olenellus truncatooculatus* sp. nov., *Mummaspis oblisooculatus* gen. et sp. nov. *Olenellus muralensis* sp. nov. coexiste avec *O. truncatooculatus* sur des blocs détachés de sorte qu'il est présent dans la zone à *Bonnia–Olenellus*. *Laudonia amputata* sp. nov. provenait d'un intervalle non déterminé, mais probablement peu éloigné de la limite. *Gabriellus lanceatus* gen. et sp. nov. est bien au-dessus de la limite où on l'a repéré dans la partie inférieure de la zone à *Bonnia–Olenellus* médiane.

PREVIOUS INVESTIGATIONS

In 1912, C.D. Walcott (1913a), then Secretary of the Smithsonian Institution, made an outstanding but incomplete collection of olenellid trilobites from an isolated talus locality in the Mount Robson area (Fig. 1). The locality, 61k, contains fossils in debris deposited at the western margin of Mumm Peak (Fig. 2). Walcott mentioned that the fossiliferous blocks were in a location "where rain, fog, and snow squalls may be expected nearly every day of the year" (1913a, p. 310). Adverse weather conditions probably affected Walcott's work, for he first miscorrelated the talus blocks with the Mahto Formation (1913a), and then with the Hota Formation (1913b, 1928, p. 253). Ironically, the miscorrelations were with formations that Walcott (1913b, 1928) was in the process of erecting in measured sections nearby. As will be shown below, most of the fossils had come from yet another formation, the Tah Formation (=Mural Formation), that he was erecting in the same sections.

In his description of the fossils from locality 61k, Walcott (1913a) reported four olenellid species, all new, which he assigned to *Callavia eucharis, Callavia perfecta, Olenellus truemani,* and *Wanneria occidens*. He also mentioned that "There is undoubtedly a larger fauna to be obtained . . . but to find it will require a camp near the locality on Hitka Pass and thorough collecting under adverse conditions."

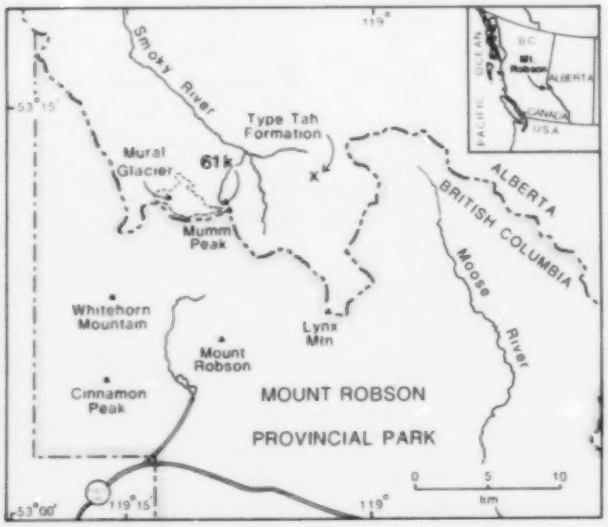


Figure 1. *Locality map of the Mount Robson area. Locality 61k (lat. 53°11'30"N; long. 119°09'30"W) is located immediately west of Mumm Peak and just north of the Mount Robson Provincial Park boundary. The Cinnamon Peak–Whitehorn Mountain section is between the mentioned peaks, "X" marks the location of the type Tah Formation (see Figure 2 for sections).*

Although Walcott (1913d, p. 639) reported to have ". . . found the bed from which this [first found fossiliferous] block had come . . .", his failure to include helpful stratigraphic data, and his lumping of an unlikely association of fossils under one locality (61k) suggests that he did not. Furthermore, the rock matrix surrounding the fossils, plus the degree of weathering exhibited by the blocks (see below), suggest that the "bed" was probably a rich talus accumulation at the foot of Mumm Peak, and not an outcrop protruding from the nearby slope.

In 1913, Walcott returned to the Mount Robson sections to complete work that had been hampered by inclement weather in 1912 (1914a, p. 8, 1914b). He was accompanied by his two sons, Sidney and Stuart, both known to have been experienced fossil collectors. Walcott made no explicit mention of re-collecting locality 61k, but his report (1914b, p. 5) of better weather and his known zeal for fossil collecting are reasons to believe that he did.

In 1915, Burling (1916a, b) visited the talus locality at the base of Mumm Peak, where his associate located a block containing a new species, *Olenellus robsonensis* (Burling, 1916a). Burling assigned his species to locality 61k and said that the block had come from the Mahto Formation. He (1916a, p. 55, 56) also included some thoughts on advanced, as opposed to primitive, olenellid features, but did not raise the possibility that the talus collection had come from several stratigraphic horizons.

Burling returned to the talus locality in 1917, and from his investigations on adjacent Mumm Peak and elsewhere, gained some insight into the local olenellid biostratigraphy. He (1918, p. 145) stated that "Evidence secured would seem to indicate that while the *Callavia* (=*Nevadella*) and *Olenellus* zones are hardly to be separated as such in this region, *Callavia* does appear alone in the section first, later mingles with *Olenellus,* and finally disappears, leaving *Olenellus* alone." After mulling over his 1917 data, Burling (1922, 1923) concluded that the talus blocks had not come from the Hota Formation, as indicated by Walcott, or the Mahto Formation, as stated by both himself and Walcott, but from the Tah Formation. Burling (1923, p. 746) further reported that the 61k fauna had come from a horizon 550 ft. (168 m) below the top of the Tah on Mumm Peak.

Because Burling felt that the type Tah lacked qualifications for formal status, he (1923, p. 744)

Figure 2. View looking west toward Mural Glacier (glacial field in centre skyline). Dark ridge at left is part of Mumm Peak; Mahto-Mural formational contact in measured section is at "a". McNaughton-Mural formational contact is exposed on Mural Wall at "b", and on Gendarme Mountain at "c". Estimated position of locality 61k is "d", which is the former margin of the glacier (glacier now in retreat). Photograph is from Fritz and Mountjoy, 1975. (GSC photo. 201307L.)

proposed a new formation, the Mural Formation, with a type section on Mumm Peak to take its place. From his posthumous publication of 1928, it is clear that Walcott did not accept Burling's Mural Formation, and he continued to believe that the fossiliferous blocks had come from the Hota Formation (op. cit., p. 362). For his part, Burling (1955) maintained his 1923 position on both the validity of the Mural Formation and Mural origin of the 61k fossiliferous blocks. He did, however (op. cit., p. 36), add that the type Tah differed significantly "in lithology and fauna" from the type Mural, and therefore he extended to others a choice of using either the Tah or the Mural Formation where appropriate in a given area.

Lochman (1952, p. 97) reviewed the 61k collection while in the process of describing trilobites from Mexico, and noted that within the 61k collection ". . . several cephala occur which have never been described". She considered one of these undescribed cephala (probably that of *Laudonia bispinata*) to be conspecific with her new species and subspecies, *Wanneria mexicana prima*, in the Mexican collections.

Harrington (1956) later described *Laudonia bispinata* for the first time from a single cephalon collected by L.R. Laudon from the "Mahto formation, Mumm Peak". He noted that Lochman's Mexican specimens belonged to *Laudonia*, but rightly observed that the subspecies and species were not the same. From Lochman's text, Harrington must have known she had seen two species of *Laudonia* in the 61k collections, but it is unlikely that Harrington viewed the 61k material, for if he had, his description and illustration would have been supplemented by more skeletal parts and better material.

In 1959, R.V. Best illustrated seven species from Walcott's 61k collection in his Ph.D. thesis on North American olenellid trilobites. Three species and one genus

were considered new, but they did not receive formal recognition because Best's thesis was not published. His illustrations did, however, provide the first irrefutable documentation (to a limited readership) that the material from locality 61k had been augmented by Walcott in 1913. No reason was offered as to why Walcott had not illustrated or even announced the additional taxa, but it can be assumed that Walcott had been diverted by the even more attractive fauna from the Burgess Shale.

In 1973, Mountjoy and I (Fritz and Mountjoy, 1975) studied Lower Cambrian strata and biostratigraphy on Mumm Peak and in Walcott's nearby sections. These data were integrated with those from my nearby 1971 section (Fritz, 1972a) measured between Cinnamon Peak and Whitehorn Mountain (Fig. 1). Our work showed that Walcott's type Tah was adequately defined, and that Burling had correctly recognized the formation's position on Mumm Peak. We (Fritz and Mountjoy, 1975, p. 120, 122) agreed with Burling's view that the 61k fossils had come from the Mural (= Tah) Formation, and we were able to locate accurately the boundary between the *Nevadella* Zone and *Bonnia-Olenellus* Zone in the middle member of the Mural. Although we saw no justification for Burling's having erected the Mural Formation, we favoured its continued use, because it had by that time become widely entrenched in the literature, whereas the Tah had not. It should be added here that the Tah should not even be used locally, as implied by Burling, because the lithotypes and thicknesses at the two type sections are too similar to justify both names.

Before visiting the Mount Robson area, I had been puzzled by Burling's statement on the overlapping ranges of *Nevadella* and *Olenellus* in the Mount Robson area (see also Poulsen, 1932, p. 60; Raw, 1936, p. 244, 250; Okulitch, 1951, p. 406; Tasch, 1952, p. 485; Lochman and Wilson, 1958, p. 318; Kielan, 1960, p. 90, for uncritical acceptance of overlap). I had not seen this overlap in the field, and in fact had considered the interval between uppermost *Nevadella* and lowermost *Olenellus* occurrence to be the boundary interval between the *Nevadella* and *Bonnia-Olenellus* zones (Fritz, 1972b). A museum review of the 61k material had also produced evidence against an overlap. *Nevadella* was not found with other olenellids on slabs, whereas *Olenellus* was found along with expected post-*Nevadella* Zone taxa on other slabs. In the Mount Robson area, at the Cinnamon Peak–Whitehorn Mountain and Mumm Peak sections, the uppermost *Nevadella* was found as close as 10.4(?) m and 0.3 m, respectively, below the lowest *Olenellus* occurrence (Fig. 3a). Having reviewed the above observations, I conclude that the 61k collection represents fossils from two distinct zones.

Although this work refutes Burling's reported overlap, it supports his (1923, p. 746) observation that collection 61k came from drift blocks in a lateral moraine. It is suspected that the blocks had been glacially plucked, because scree from the local mountainside, and rock in adjacent outcrops as well, are more deeply weathered than the slabs in the 61k collection. In addition, trilobites in local mountainslope talus and outcrops were found to be less well preserved and of smaller average size. It was not possible in 1973 to directly compare lateral moraine material at the base of Mumm Peak with slabs in the 61k collection, because by 1973 the moraine had become overgrown with vegetation following the glacier's retreat.

To summarize, between 1913 and 1975 the successive biostratigraphic positions allotted to locality 61k underwent numerous changes. The various horizons to which locality 61k was assigned can be best expressed in terms of today's zonation. The position of the 61k "subfauna" was reported to be in the medial part of the *Bonnia-Olenellus* Zone (Walcott, 1913a; Burling, 1916a, 1916b; Mahto Fm.) and in the upper part of that zone (Walcott, 1913b, 1913c, 1928, p. 362; Hota Fm.). Burling's (1922, 1923) revised location (the Mural Fm.) was more accurate for most of the collection, because this placed it near the boundary between the *Nevadella* and *Bonnia-Olenellus* zones. However, his statement (1918) that *Nevadella* "mingles" (overlaps) with *Olenellus* proved to be incorrect, and it obscured the fact that the "subfauna" came from various horizons on either side of a zone boundary. The work of Fritz and Mountjoy (1975, Fig. 2) agrees with Burling's assignment of the 61k collection to the Mural, and it accurately locates the boundary between the *Nevadella* Zone and the *Bonnia-Olenellus* Zone within the middle member of the Mural. The density of Fritz and Mountjoy's collecting localities near that boundary suggests that these strata were the source of the 61k material.

LOCAL BIOSTRATIGRAPHY AND LOCALITY 61K

The lithology and age of the Mural Formation in the Cinnamon Peak–Whitehorn Mountain, Mumm Peak, and type Tah sections were described by Fritz and Mountjoy in 1975. In Figure 3, their 1975 data is supplemented, and more local stratigraphic detail and trilobite ranges are given. The cluster of critical ranges in the lower half of the middle mudstone member of the Mural Formation in the Mumm Peak section indicates that this was the main source of Walcott's 61k collection.

At the Cinnamon Peak–Whitehorn Mountain and Mumm Peak sections, the boundary between the

Nevadella and *Bonnia–Olenellus* zones is within the intervals 4.1 m below to 6.2 m above and 14.2 m to 14.5 m above the base of the middle mudstone member, respectively. At the type Tah, the middle member is covered, and therefore was nonproductive. However, a close match of the lithology within the upper and lower members of the Mural Formation at all three sections leaves little doubt that the boundary between the *Nevadella* Zone and the *Bonnia–Olenellus* Zone is within the lower part of the middle member or close below the lower–middle member contact.

In the Cinnamon Peak–Whitehorn Mountain section, *Nevadella* or *Nevadia* is immediately below the *Nevadella* and *Bonnnia–Olenellus* zone boundary interval, and *Olenellus truemani*? is immediately above, closely followed by *Laudonia bispinata*. The same succession is present in the Mumm Peak section, where the strata are less weathered and sheared, and more detailed faunal identifications can be made. Below the Mumm Peak boundary interval, *Nevadella perfecta* was collected at seven horizons, some of which contained the species in abundance. *Nevadella eucharis* underlies *N. perfecta*, and is known from only one locality (GSC loc. 90566). The rarity of *N. eucharis* is not surprising, as only one specimen (the holotype) was found in the 61k collection. A new species, *Nevadella mountjoyi*, underlies *N. eucharis*, but is still within the medial siltstone member of the Mural Formation. The brachiopod *Mickwitzia*? is locally abundant in the upper *Nevadella* Zone, having been found there in the 1973 field localities, and is also associated with *N. perfecta* on 61k blocks. *Mickwitzia*? was not found above the *Nevadella* Zone in the 1971 and 1973 collections, but it does occur on 61k blocks with *Olenellus truemani*, and therefore is believed to extend a short distance into the overlying *Bonnia–Olenellus* Zone.

At the two productive sections, fossils were found in the lower half of the middle member, but not in the upper half. The lithology of the upper half is similar to that below, and no obvious reason could be found to explain the lack of fossils.

It has been mentioned that at the type locality of the Tah Formation, the middle member of the Tah (= Mural) is covered, and no fossils were obtained. The presence of aff. *Bradyfallotaspis* at the base of the lower (limestone) member in this section indicates a *Nevadella* Zone age for that horizon. The close lithological similarity of this member at the site of the three sections, and the close geographic proximity of the three, plus the presence of *Nevadia weeksi* near the base of the Mural at the Cinnamon Peak–Whitehorn Mountain section (Fig. 3a, GSC locs. 87898, 87899), indicate a low position within the *Nevadella* Zone for the base of the Mural. A new species of *Nevadia*, *N. parvoconica*, was found at approximately the one-sixth level (GSC loc. 90563) below the top of the lower member in the Mumm Peak section, and an undescribed species of *Nevadia* was collected at approximately the same level (GSC loc. 87896) in the Cinnamon Peak–Whitehorn Mountain section.

Olenellus truemani is abundant above the boundary interval in the Mumm Peak section, where *Mummaspis occidens* occurs immediately above the interval. In the Cinnamon Peak–Whitehorn Mountain section, *O. truemani*? occurs first above the boundary and is closely followed by *Laudonia bispinata*. The latter species in the Mumm Peak section occurs together with abundant specimens of *Olenellus truncatooculatus*. *Mummaspis oblisooculatus* is present above the occurrence of *L. bispinata* and *O. truncatooculatus*.

Just above the top of the Mural in the Cinnamon Peak–Whitehorn Mountain section (GSC loc. 87889), the association of *Proliostracus* sp., *Labradoria*? sp., and *Bonnia* sp. indicates the medial part of the *Bonnia–Olenellus* Zone. Near the same horizon in the Mumm Peak section, *Bonnia* sp., *Olenellus* sp. cf. *O. laxocules* Fritz, 1972b, *Mummaspis* sp. cf. *M. oblisooculatus* sp. nov., *Proliostracus contractus* Fritz, 1972b, and *Gabriellus lanceatus* gen. et sp. nov. are present in local float (GSC loc. 90579). The presence of *P. contractus* indicates the lower part of the medial *Bonnia–Olenellus* Zone. *Olenellus* sp. cf. *O. laxocules* suggests a medial position within the zone. The occurrence of *Mummaspis* sp. cf. *M. oblisooculatus* at this level and *M. oblisooculatus* in the lower *Bonnia–Olenellus* Zone (GSC loc. 90578) provides a questionable range of the species into two subdivisions of the zone.

Gabriellus is rare in the Mount Robson area, being represented by a single cephalon in the 61k collection plus a tentatively assigned prothorax, and by two cephala in a 1973 collection from above the top of the Mural (GSC loc. 90579). The same genus has been reported (Best, 1959; Whittington, 1989) from an undesignated horizon in the Cassiar Mountains, British Columbia (Fig. 4, loc. 2). A review of my Geological Survey of Canada collections from that area indicates that the genus occupies unit 4 of the Rosella Formation (see Fritz, 1978b, Fig. 3.1a, section 2). There it is located in approximately the same zonal interval as in the Mumm Peak section.

Burling (1916b, p. 100) considered his species, *Olenellus robsonensis* (Burling), to be part of Walcott's "subfauna" in locality 61k. However, no evidence was found to support this belief. Burling's species is based

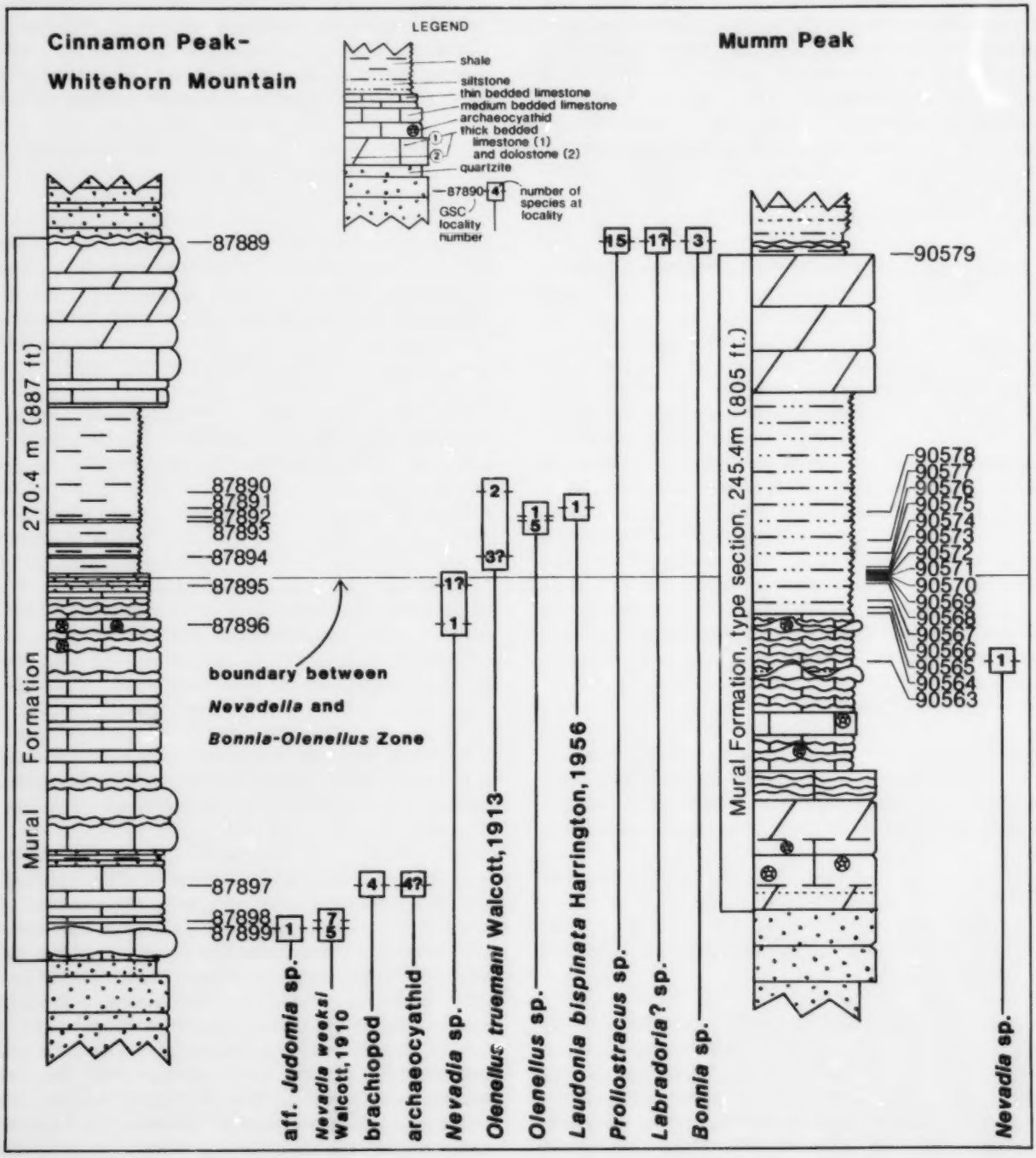
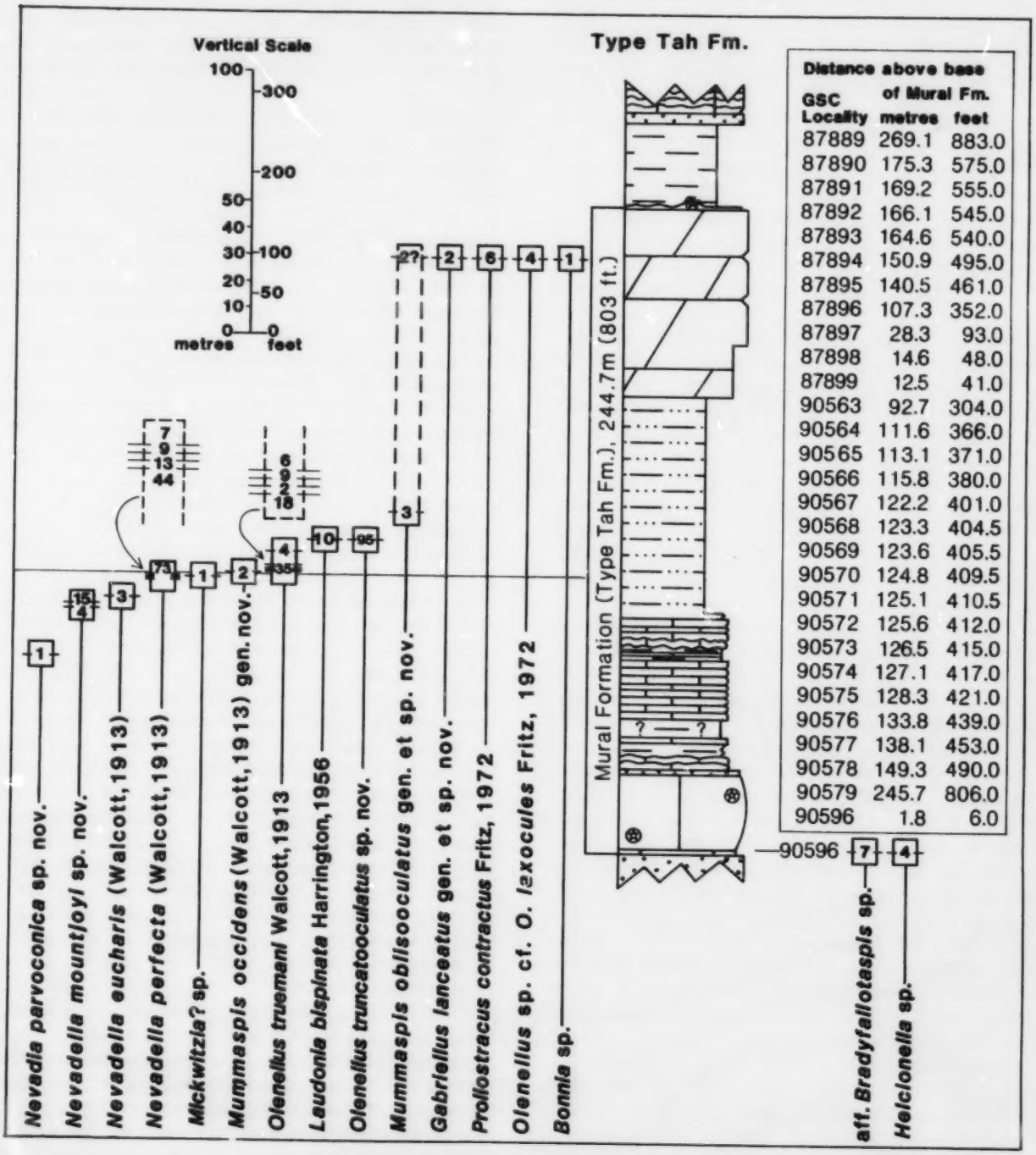


Figure 3. Stratigraphic sections and range chart for GSC fossils collected in 1971 and 1973. Many of the species mentioned are the same as those present in Walcott's collection from locality 61k. Geographic location of sections is shown in Figure 1. See Fritz and Mountjoy, 1975, Figure 2 for illustration of complete sections.



GSC Locality	Distance above base of Mural Fm. metres	feet
87889	269.1	883.0
87890	175.3	575.0
87891	169.2	555.0
87892	166.1	545.0
87893	164.6	540.0
87894	150.9	495.0
87895	140.5	461.0
87896	107.3	352.0
87897	28.3	93.0
87898	14.6	48.0
87899	12.5	41.0
90563	92.7	304.0
90564	111.6	366.0
90565	113.1	371.0
90566	115.8	380.0
90567	122.2	401.0
90568	123.3	404.5
90569	123.6	405.5
90570	124.8	409.5
90571	125.1	410.5
90572	125.6	412.0
90573	126.5	415.0
90574	127.1	417.0
90575	128.3	421.0
90576	133.8	439.0
90577	138.1	453.0
90578	149.3	490.0
90579	245.7	806.0
90596	1.8	6.0

Figure 3. (cont'd.)

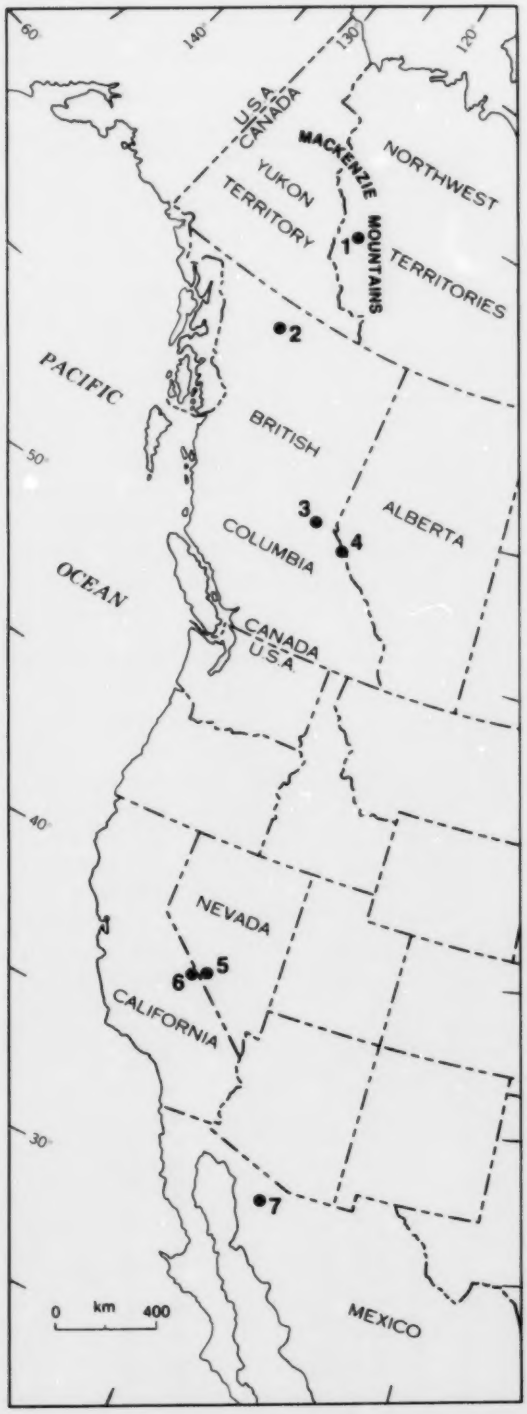


Figure 4. Map of fossil collecting sites in 1) Mackenzie Mountains, 2) Cassiar Mountains, 3) Cariboo Mountains, 4) Mount Robson area, 5) Slate Ridge, 6) White-Inyo Mountains, and 7) Caborca area.

upon a single specimen found ". . . on the slope of the Mural glacier just under Mumm Peak . . ." (Burling, 1916a, p. 55). The rock matrix surrounding *O. robsonensis* is a nearly black, pyrite-bearing mudstone that contrasts with the lighter, more shaly mudstone of typical 61k blocks. This lithology, the absence of *O. robsonensis* in my 1971 and 1973 samples and in the 61k collection, and a resemblance of *O. robsonensis* to younger olenellids, suggest that it came from a higher horizon, very probably well up in the Mahto Formation.

Although only a limited number of olenellids are described in this paper, their morphology and abrupt change across a narrow zonal boundary interval deserve some consideration. Of the trilobites immediately below the boundary interval, only the genus *Nevadella* is known. Above the boundary are two short-lived genera, *Mummaspis* and *Laudonia,* followed by short-lived *Gabriellus* somewhat higher. *Olenellus*, which continues throughout the overlying *Bonnia–Olenellus* Zone, exhibits a remarkable plasticity near the base of the zone. Cephala of *O. truncatooculatus* could readily be mistaken for those of *Wanneria* if isolated from the remainder of the exoskeleton. The metagenal spine position (spine only incipiently developed) on *O. truemani* and *O. muralensis* is more distal than one would expect for species this low in the *Bonnia–Olenellus* Zone. The deceptive appearance of the last two species led Walcott in 1916 (p. 253) to equate them in age with *Olenellus thompsoni* (Hall, 1859), a species known to him to occupy high Lower Cambrian strata in the Appalachians. Walcott continued to believe that *O. truemani* "looked young", for in 1928 (p. 253) he equated the 61k collection in age with fossils that were later located by Rasetti (1951, p. 54) as having come from the uppermost Lower Cambrian (Peyto Fm.) in the southern Canadian Rocky Mountains. Walcott's continued belief that certain olenellids in the 61k collection came from strata of the uppermost Lower Cambrian was undoubtedly a major reason for his refusal to accept Burling's evidence that they had come from an older (Mural Fm.) position in the Mumm Peak succession.

It is too early in Cordilleran investigations to offer more than a few suggestions to explain the abrupt change across the lower boundary of the *Bonnia–Olenellus* Zone, and the rapid evolution above the base of the zone. In the Mackenzie Mountains (Fig. 4, loc. 1), redbeds and a quartzite unit mark the boundary within the lower half of Grand Cycle B, indicating a recession at the time of the faunal change (Fritz, 1976, p. 2). Elsewhere in the Cordillera, there are a number of localities where the boundary is within a siltstone unit that may represent the same regression (Fritz, 1975; see also Regional Correlations, below). It is therefore possible that the

abrupt faunal change at the boundary reflects a disconformity produced by a eustatic stillstand or slight uplift. This regional recession concept only partially explains the magnitude of this change, however, and does not explain what appears to be rapid evolution above it.

At the Mumm Peak section, the boundary lies within a narrow interval, is faunally abrupt, and is within a lithologically uniform succession. These are a few of the attributes commonly used to describe a biomere boundary. However, a biomere boundary is underlain by a diverse fauna and overlain by a limited fauna (Palmer, 1984, p. 605), whereas at Mumm Peak the boundary displays the opposite relationship. If, however, a biomere boundary had been registered in detail and had then been erased by erosion, or had not been registered locally because of nondeposition, the remaining evidence might not look too different from that at Mumm Peak. The initial, limited fauna phase may have been eroded or not deposited, and the intermediate, diversification phase may have been the first to be recorded.

REGIONAL CORRELATIONS

In the Mackenzie Mountains (Fig. 4, loc. 1), trilobites assigned (Fritz, 1976, 1978a, 1979) to *Laudonia*?, *Fremontella*?, and "*Esmeraldina*" suggest a close correlation of part of the Sekwi Formation with the lowermost *Bonnia–Olenellus* Zone trilobites in locality 61k. Upon reviewing the Sekwi material, however, it was found that those trilobites questionably placed under the first two genera fit better under *Bristolia*. Mackenzie Mountain trilobites assigned to "*Esmeraldina*" superficially resemble *Mummaspis*, especially in bearing a large occipital spine, but differ in many other respects (see *Mummaspis* under Systematics, below).

Gabriellus also occurs in a Sekwi locality (Fritz, 1979, GSC loc. 94577) at the base of the medial third of the *Bonnia–Olenellus* Zone. This occurrence, and the similar occurrence in the Cassiar Mountains, suggest that *Gabriellus* may be useful for refining correlations.

The position and abundance of *Olenellus truemani* in the Mount Robson area and its reported occurrence in the Mackenzie Mountains suggests that this species could be used to correlate the lowermost part of the zone between the two areas. However, a review of *O. truemani* from the Mackenzie Mountains (see discussion under Systematics, below), suggests that the identifications of *O. truemani* from the Mackenzie Mountains should be downgraded to questionable, due to both slight differences in morphology and a higher occurrence in the succession. No other species in the 61k collection have yet been identified in the Mackenzie Mountains.

In the Cassiar Mountains (Fig. 4, loc. 2; Fritz, 1978b, section 2), I collected a fauna containing various species of *Laudonia*? (GSC locs. 95189–95193) overlain by a fauna containing *Gabriellus* sp. undet. and *Olenellus* (GSC locs. 95194–95198). The order of genus occurrence is the same as at Mumm Peak. No evidence of an older fauna was found in the few metres of exposed, barren strata below, but stratigraphic correlation with a nearby section (op. cit., section 1) indicates that the *Laudonia*? fauna closely overlies the boundary between the *Nevadella* and the *Bonnia–Olenellus* zones.

In the Cariboo Mountains (Fig. 4, loc. 3), where the middle (mudstone) member of the Mural Formation is 98.4 m thick, the boundary between the *Nevadella* and *Bonnia–Olenellus* zones is within a 39.6 to 51.5 m interval above the base of the member. At the base of this interval, GSC loc. 82781 contains *Bradyfallotaspis* sp. and *Nevadella*? sp. At the top (GSC loc. 82782) are *Olenellus* sp. and *Laudonia*? sp. cf. *L.*? *mexicana* (Lochman, 1952).

In 1974, I visited Esmeralda County, Nevada, to inspect the boundary between the *Nevadella* and *Bonnia–Olenellus* zones within a section through the Poleta Formation on Slate Ridge (lat. 37°22′37″N; long. 117°16′15″W). At this section (Fig. 4, loc. 5) the Poleta exhibits a remarkable resemblance to the Mural Formation in the Mount Robson and Cariboo Mountain areas. The zone boundary was located between float collections (GSC locs. 91405, 91406) estimated to be within the approximate interval 78.9 to 81.1 m above the base of the 193.5 m middle mudstone member of the Poleta. *Nevadella* and *Bradyfallotaspis* were found at various levels below the boundary interval, and *Bristolia* or *Laudonia, Olenellus*, and *Labradoria* at various levels above. The reported (Albers and Stewart, 1972, p. 13, 14) overlap of the range of *Laudonia* with that of *Nevadella, Laudonia* with that of *Judomia*, and *Olenellus* with that of *Judomia* in that region remains suspect, because these relationships were not seen at the Slate Ridge section.

West of Slate Ridge, in the White–Inyo Mountains of California (Fig. 4, loc. 6), Nelson and Durham (1966) showed overlapping ranges of *Laudonia* with *Judomia, Holmia, Nevadia*, and *Nevadella*. These reported associations were corrected by Nelson (1978, Fig. 3), who showed the boundary between the *Nevadella* and *Bonnia–Olenellus* zones to be located within the middle mudstone member of the Poleta Formation. *Nevadella* is located below and *Olenellus, Fremontia* and *Laudonia* above. In 1971, I measured a section in this area (lat.

37°18′29″N; long. 118°06′2″W) and found the middle member of the Poleta Formation to be 112.8 m thick. The boundary between the *Nevadella* and *Bonnia–Olenellus* zones was within the interval 73.1–83.5 m above the base of the member. *Nevadella* was found immediately below the interval, and a species of *Olenellus*? with moderately advanced spines was found immediately above. A small *Olenellus*? with some similarities to *Laudonia* and *Bristolia* was collected 22.2 and 25.5 m higher.

Lochman (1952) illustrated a species of *Laudonia*, found near Caborca, Mexico (Fig. 4, loc. 7), which she named *Wanneria mexicana prima*. The locality given was the lowest trilobite-bearing locality (801c) then known in the area. She wrote (op. cit., p. 97) that "The occurrence of both this species of *Wanneria* and *Olenellus truemani* Walcott together in the Hota shale and the Mexican section suggests a close relationship between the faunas". I believe Lochman's intentions were correct in establishing a correlation of her *Laudonia mexicana*-bearing strata in the Mexican Puerto Blanco Formation with the *Laudonia*-bearing blocks in locality 61k (but not with the Hota Fm.). Her reported Mexican association of *Olenellus truemani* with *Laudonia* was not substantiated elsewhere in her publication, however, because under her description of *O. truemani* (op. cit., p. 91) she only listed much higher (Buelna Formation) horizons for this species. Her figured specimens of *O. truemani* (also from the Buelna) probably do not belong to that species. The Mexican biostratigraphic relationships are further confused by the range chart of Stewart et al. (1984, Fig. 9) that is based on composite data from the Caborca region. In the chart, *Olenellus* sp. ranges well below *Laudonia* and overlaps cf. *Nevadia*.

In reviewing the above regional data, it is notable that at many locations the *Laudonia* fauna is poorly represented, and in some cases, such as the Mackenzie Mountains, the occurrence of an unquestionable *Laudonia* has yet to be documented. In the Mackenzie Mountains area, the base of the *Bonnia–Olenellus* Zone is within or very near a thin, *Skolithos*-bearing quartzite subunit located within the lower half-cycle of Grand Cycle B (Fritz, 1975). Within this half-cycle, redbeds are prominent at various localities, and sparse limestone interbeds containing abundant but highly fragmented olenellid exoskeletons are common. Fragments bearing a polygonal pattern (see examples of pattern in Plates 10–13) suggest that *Laudonia* and *Mummaspis* may eventually be identified at this level in the area. If this half-cycle is as widespread as thought (Fritz, 1975), and if it represents a regional regression during lower and early medial *Bonnia–Olenellus* Zone time, it is possible that the 61k fossils were deposited in a rare, limited area of low energy deposition. If so, finding the 61k trilobites was yet another demonstration of Walcott's remarkable ability to find fossils. As usual, he (1913c, p. 8) was quick to grasp the significance of this find, and announced that locality 61k "promises to give the finest specimens from the Lower Cambrian rocks of the western side of the continent."

ACKNOWLEDGMENTS

C.D. Walcott deserves first mention here, because the best of the trilobites presented in this paper are the product of his collecting efforts. S. Carbonne assisted me in measuring the Cinnamon Peak–Whitehorn Mountain section in 1971. In 1973, guidance and help in measuring the Mumm Peak and type Tah Formation sections was given by E.W. Mountjoy, McGill University. Mountjoy's field assistant, M. Hauseneau, helped with these two sections, and his wife, Marguerite, cooked and maintained the field camp. Arrangements for the study of the 61k collection at the United States National Museum of Natural History and for later fossil loans were made by F.J. Collier, Smithsonian Institution. Two small trilobite collections from the 61k area were loaned to me for inspection. One collection was loaned by T.S. Laudon, son of the collector, L.R. Laudon. The other collection, made by A. Wright, was loaned by G.D. Edgecombe, American Museum of Natural History. Photography, construction of plates, and drafting of figures were accomplished by H. McLaughlin. Helpful suggestions that improved the manuscript were offered by H.B. Whittington and A.R. Palmer. To all of those mentioned, I extend my grateful appreciation.

SYSTEMATIC PALEONTOLOGY

The systematics and nomenclature used here conform in general to those presented in the Treatise on Invertebrate Paleontology (Moore, 1959). Genera have been arranged under families following a recent classification scheme by Ahlberg et al. (1986). The occipital ring is here considered to be part of the glabella, and the fifteenth segment (bearing a macrospine) on Olenellidae is included in the prothorax. Unless otherwise indicated, all cephalic lengths given are sagittal lengths.

Most of the fossils figured in this publication are from Walcott's locality 61k, and are housed in the United States National Museum of Natural History (USNM), Washington, D.C. Burling's smaller collection (18c), which is probably from the same locality, is in the same institution. The remaining figured specimens (GSC) are from my 1973 collections, which are stored in the National Type Collection of Plant and Invertebrate

Fossils, Geological Survey of Canada, Ottawa. Supporting fossil collections made by me during 1971 and 1973 in the Mount Robson area (GSC locs. 87889–87899, 90563–90579, 90596) and in the six other areas mentioned under "Regional Correlations" are stored among the Geological Survey of Canada field collections in Ottawa.

The quantities of trilobite specimens belonging to various species in my Mount Robson collections and in locality 61k are given in the systematic descriptions under "Material". The species and number of specimens in Burling's 18c collection are as follows: *Mummaspis oblisooculatus*? (5), *Olenellus truemani* (3), *Olenellus truncatooculatus* (14).

Family Olenellidae Walcott, 1890

Genus *Olenellus* Hall, 1861

1910 *Olenellus* Hall; Walcott, p. 311 (synonymy to date).
1972b *Olenellus* Billings; Fritz, p. 11 (synonymy 1910–1972).
1979 *Olenellus* Billings; Palmer *in* Palmer and Halley, p. 66.
1979 *Olenellus* Billings; Repina, p. 22.
1989 *Olenellus* Hall; Whittington, p. 114.

Type species. Olenellus thompsoni (Hall, 1859).

Olenellus muralensis sp. nov.

Plate 8, figures 1–7, Plate 9, figure 1; Figure 5c

1913a *Olenellus truemani* Walcott (part), Pl. 54, figs. 7, 9(?), 10(?)
1916 *Olenellus truemani* Walcott; Walcott, Pl. 17, figs. 7, 9(?), 10(?).

Etymology. The trivial name refers to the Mural Glacier, which transported the fossils now in collection 61k.

Material. Sixty-three cephala from locality 61k ranging from 5.6 to 17.0 mm in length, eight of which have partial or complete prothoraxes attached. Two blocks contain specimens of both *Olenellus muralensis* and *Olenellus truncatooculatus*. One of these blocks also contains *Mummaspis oblisooculatus* and *Laudonia bispinata*?. Therefore, even though *O. muralensis* was not found during the 1973 and 1975 field seasons, it can be assumed the species came from the lower part of the *Bonnia–Olenellus* Zone.

Description. Cephalon approximately half as long as wide, semicircular in outline. Anterior glabellar lobe (L4) and anterior pair of glabellar lobes (L3) have combined outline (excluding ocular lobes) of incomplete parabola; anterior margin of ocular lobes enter parabola at widest point. Parabolic curvature ends at second pair of lobes (L2), where posterior convergence at lateral margin becomes less rapid. Anterior glabellar lobe touches, or nearly touches, anterior border furrow. Axial furrows diverge slightly outward and backward from first (S1) pair of glabellar furrows to midpoint on lateral margin of occipital ring, then converge slightly to base of ring. Anterior (S3) and medial (S2) pairs of glabellar furrows arcuate and nearly parallel, average inclination of anterior pair is slightly forward, medial pair transverse. Posterior pair (S1) nearly straight and inclined slightly backward. Distal segments of occipital furrow nearly transverse. Glabellar furrows and distal segments of occipital furrow weakly or not joined across midline on numerous cephala; anterior and second pairs (S3, S2) joined on those cephala distorted by greater than average compaction. Anterior (L3) and second (L2) pairs of glabellar lobes of equal length along axial furrow, posterior pair (L1) considerably longer and slightly longer than occipital ring. Ocular lobes directed strongly outward at base, uniformly curved along outer margin, terminating opposite occipital furrow. Ocular furrow narrow, strongly incised throughout length. Anterior and lateral border of medium, uniform width, except where slightly expanded at genal angle. Outer margin of genal spine continues curvature of cephalic margin, spine nearly half as long as cephalon. Posterior border of uniform width, transverse along proximal four fifths, distal fifth narrowing and angling forward to moderately but distinctly advanced genal spine. Metagenal spine on large cephalon weakly or not developed at point four fifths of distance from proximal end of posterior border; on medium-sized cephala metagenal spine is short and directed strongly out and backward. Metagenal ridge faint, inclined steeply backward and outward from near axial furrow, then broadly curved along proximal half to approach anterior margin of posterior border at low angle. Remaining half of ridge not clearly visible, but probably continuing outward in contact with border. Occipital ring bears small spine near posterior border.

Thoracic segments generally decrease in width (exsag.) in posterior direction, inner pleurae on second and third widest, having longest spines, third only slightly larger than second. Spine on first pleura considerably shorter than on second and third. Macrospine on fifteenth segment well developed at base, total length unknown (broken). Seventh through fourteenth axial rings bear spines (spine areas on first to sixth too poorly preserved for observation).

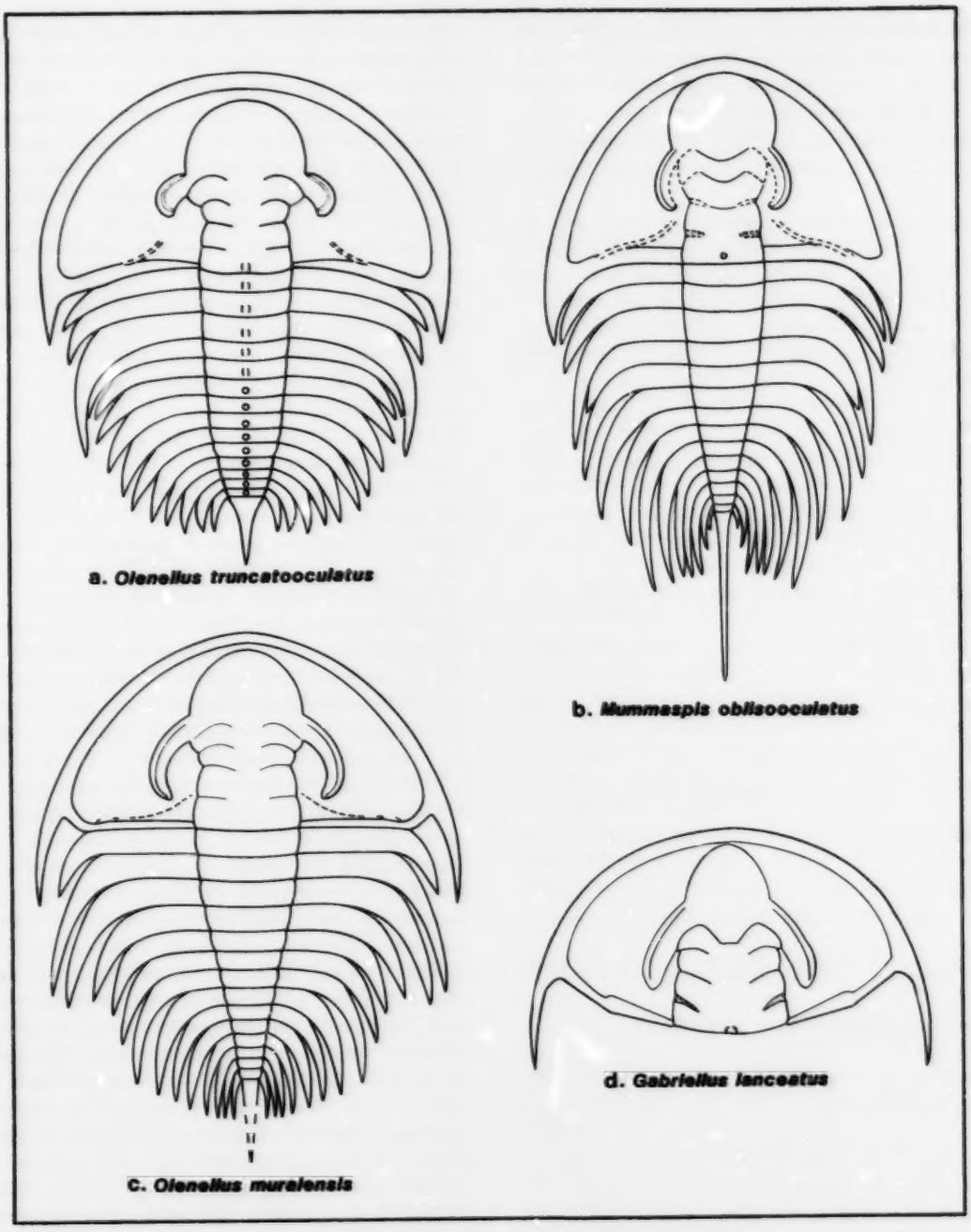


Figure 5. *Line drawings showing cephala with attached prothoraxes of* ***a) Olenellus truncatooculatus*** *sp. nov.,* ***b) Mummaspis oblisooculatus*** *gen. et sp. nov., and* ***c) Olenellus muralensis*** *sp. nov., and cephalon of* ***d) Gabriellus lanceatus*** *gen. et sp. nov.*

Ornamentation consists of terrace lines on anterior and lateral border and on genal spine, weak venation on extraocular area, weak polygonal network on interocular area and in thoracic pleural furrows.

Discussion. Olenellus muralensis specimens were figured by Walcott (1913a, 1916) with specimens of *Olenellus truemani* and all were placed under the latter species (see also discussion under *O. truemani*). Lochman (1952,

p. 91) noted that there is considerable variation in Walcott's figured specimens of *O. truemani*, but she attributed this to "shale preservation". Best (1959, p. 97, in Kielan, 1960, p. 88) remarked that Walcott had figured "at least" two species under *O. truemani*. He cited Walcott's figured specimens by number to clarify his concept of how the specimens should be grouped into two species, but failed to provide a lectotype and holotype in order to designate his groups by name. I disagree with the composition of Best's groups, but do agree that Walcott had illustrated two species under one name. I here designate a specimen, which Walcott (1913a, Pl. 54, fig. 7) illustrated, as holotype for *Olenellus muralensis*, and in the following discussion under *Olenellus truemani* designate a lectotype for that species.

Olenellus muralensis differs from *O. truemani* in having a cephalon with a narrower border, more slender, advanced genal spines, a broader anterior glabellar lobe, which is not as strongly curved at the front, and longer ocular lobes. The more distal position of the metagenal spines differentiates *O. muralensis* from many species of *Olenellus* in the lower and medial parts of the *Bonnia–Olenellus* Zone. *Olenellus romensis* Resser and Howell, 1938 in the upper part of the zone resembles *O. muralensis*, but differs in having a cephalon that is more broadly curved along the front margin and an anterior glabellar lobe that extends farther forward.

Olenellus truemani Walcott, 1913

Plate 6, figures 1–4, Plate 7, figures 1–6; Figure 6b

1913a *Olenellus truemani* Walcott, p. 316, Pl. 54, figs. 2, 6(?), 8; *non* figs. 7, 9, 10.
1916 *Olenellus truemani* Walcott; Walcott, Pl. 17, figs. 2, 6(?), 8; *non* figs. 7, 9, 10.
(?)1972b *Olenellus truemani* Walcott; Fritz, p. 16, Pl. 9, figs. 1–14.

Material. Forty-four cephala from the following GSC localities: 87894 (3?), 87890 (2), 90572 (18), 90573 (2), 90574 (9), 90575 (6), 90576 (4). Cephala are from 2.5 to 16.5 mm long. One prothorax without attached cephalon was collected from GSC locality 90573 and one prothorax with attached cephalon from GSC locality 90574. Approximately 182 specimens were recovered from locality 61k. In the latter collection, *Mickwitzia muralensis* Walcott occurs together with *O. truemani* on eight blocks.

Description. Cephalic outline nearly semicircular, length to width ratio approximately 11:20. Anterior glabellar lobe bullet-shaped, strongly rounded in front, nearly, but not quite reaching anterior border furrow. Anterior two pairs of glabellar lobes (L3, L2) have lateral margins that converge moderately backward to form upper half of nearly symmetrical hourglass outline; lateral margins of posterior lobes (L1) and occipital ring form lower half. Anterior and second pair of glabellar lobes approximately equal in length (exsag.); posterior pair of lobes longer, clearly longer than occipital ring. Glabellar furrows well incised, anterior pair (S3) strongly chevron-shaped, joined across midline by transverse furrow that maintains width and depth of distal segment. Medial pair (S2) arcuate, inclined slightly backward, weakly joined by broad, shallow furrow. Posterior pair (S1) nearly straight and inclined more strongly backward. Occipital furrow only slightly wider (exsag.) than glabellar furrows, distal segments inclined slightly backward, medial two fifths obsolete. Anterior and lateral borders of uniform width, in cross-section inner third of border rises steeply from extraocular area, distal two thirds slopes outward. Lateral border grades backward into flat genal spine that is directed slightly outward. Posterior border transverse or directed slightly backward, expanding slightly along proximal five ninths to widest point where entered by metagenal ridge. Metagenal ridge low and narrow, slightly wider where it angles across posterior border; no metagenal spine developed at termination of metagenal ridge at seven-ninths point from proximal end of posterior border.

Hypostome poorly known; anterior lobe extends anterolaterally into short, blunt wings, border furrow narrow and nearly effaced at posterior position. Lateral border bears 5(?) pairs of spines, posterior border without(?) spines.

Prothorax of small specimen (prothorax 11 mm long exclusive of macrospine) is equal in length to length of cephalon. Pleural spines strongly falcate, long. Macropleural or third segment half as wide again (exsag.) as adjacent segments, spines much longer than others on prothorax. Macrospine on last segment very slender, length three fifths that of preceding prothorax. Ornamentation on internal moulds consists of radial to anastomosing venation on extraocular area; small node present on occipital ring and on each of anterior 14 axial rings on prothorax.

Discussion. One of Walcott's nearly complete specimens of *Olenellus truemani* (1913a, Pl. 54, fig. 2, left, USNM no. 60084) is here designated as lectotype. In his description of *O. truemani*, Walcott illustrated specimens [ibid., figs. 7, 9(?), 10(?)] that belong to a species named *Olenellus muralensis* sp. nov. in this paper. Hypostomes assigned by Walcott (ibid., figs. 4, 5) to *O. truemani* are on the same block with specimens of *O. muralensis*.

Coarse, reticulate ornamentation mentioned by Walcott (1913a, p. 316) is not visible on internal moulds of *O. truemani* and is only lightly developed on external moulds. One specimen of *O. truemani* in Burling's collection 18c exhibits good preservation of the exoskeleton, and has an unusually strong reticulate network on the upper surface. A relatively wide cephalic border, a genal spine with a wide, flat base, and a bullet-shaped anterior glabellar lobe are combined features that separate *O. truemani* from most other species of *Olenellus*. *Olenellus praenuntius* Cowie, 1968 from Ellesmere Island was placed in synonymy with *O. truemani* by Fritz (1972b, p. 16), but should be re-established as a valid species. Although *O. praenuntius* has the general cephalic proportions of *O. truemani*, especially those of the glabella, it differs in having an anterior lobe that terminates farther back from the anterior border, ocular lobes that extend back beyond the level of the occipital furrow, and more proximally placed metagenal spines (at two-thirds mark on posterior border). The genal spines of *O. praenuntius* are slightly advanced as opposed to those of *O. truemani*, and they are more rounded in cross-section. *Olenellus reticulatus* Peach, 1894 from northwestern Scotland resembles *O. truemani* in many respects, but has a narrower border and genal spine, and the glabella terminates slightly farther back from the anterior border. Illustrated specimens of *O. truemani* from the Mackenzie Mountains (Fritz, 1972b, Pl. 9, figs. 1–14) are here relegated to a questionable status, because the cephalic borders and genal spines are narrower and the ocular lobes slightly longer.

The association of *Proliostracus depressus* Fritz, 1972b with the Mackenzie Mountain specimens, plus their higher stratigraphic position above the boundary between the *Nevadella* and *Bonnia–Olenellus* zones, indicate that they are somewhat younger than the Mount Robson specimens. Mexican cephala described by Lochman (1952) as *Olenellus* (*Olenellus*) *truemani* are too incomplete for a full comparison with the Mount Robson specimens, but they do exhibit longer ocular lobes, narrower, inward tilting anterior and lateral borders, and more constriction of the glabella at the level of the first pair (S1) of glabellar furrows. These differences indicate the Mexican material belongs to a different species.

Olenellus truncatooculatus sp. nov.

Plate 14, figures 3–6, Plate 15, figures 1–9, Plate 16, figures 1–3; Figure 5a

Etymology. Latin, *truncus*, maimed or shortened by cutting off, and Latin, *oculus*, eye, focusing attention on the truncated ocular lobes.

Material. Ninety-five cephala of *Olenellus truncatooculatus* from GSC locality 90577 having lengths of 1.5 to 13.0 mm. *Olenellus truncatooculatus* occurs together with *Laudonia bispinata* at GSC locality 90577. One hundred and ninety-eight cephala with lengths of 1.9 to 18.5 mm are in collection 61k, 10 of which have prothoraxes attached. *Olenellus truncatooculatus* occurs together on a single 61k block with *Olenellus muralensis*, *Mummaspis oblisooculatus*, and questionably with *Laudonia bispinata*.

Description. Cephalic outline semicircular, length approximately equal to width. Anterior and lateral borders of uniform width, no appreciable widening near genal angles; anterior and lateral border furrow wide and shallow. Anterior glabellar lobe terminates before reaching anterior glabellar furrow, front broadly curved, curvature notably stronger at anterolateral position and then broadly curved backward and only slightly outward to ocular lobes. Third pair (L3) of glabellar lobes swollen, distal part on anterolateral margin nearly on line (exsag.) with widest point on anterior lobe. Second pair of glabellar lobes (L2) considerably narrower (tr.) and shorter (exsag.) than third pair. Lateral margin of posterior lobes (L1) diverge slightly backward, length (exsag.) approximately equal to that of occipital ring. Occipital ring marked by transverse furrow starting at lateral margin, one third of distance from base, furrow shallows inward to become nearly extinct where passing in front of occipital node. Glabellar furrows relatively deep for olenellid, anterior pair (S3) chevron-shaped, shallowing but clearly joined across axial midline. Second pair (S2) arcuate, average inclination slightly backward, shallowing near axial furrow and shallowing to near extinction near axial midline. Posterior pair (S1) straight, deep, and wide, inclined moderately backward, very shallow near axial midline. Distal segments of occipital furrow wide and deep, abruptly shallowing inward, medial half effaced. Ocular lobes directed strongly outward, very short, ocular furrow narrow but clearly developed throughout. Posterior border inclined slightly backward or transverse, expanding along proximal quarter, remainder of uniform width (exsag.). Metagenal ridge originates near small swelling opposite posterior third of posterior glabellar lobe, inclined outward along proximal eight elevenths of length, remaining three elevenths crosses posterior border at an angle, and terminates against posterior margin without developing into metagenal spine on large- and medium-sized specimens.

Anterior two segments on prothorax of approximately equal size, both bearing short spines. Third segment considerably larger, bearing large pleural furrow and long spine. Fourth much smaller than third, fifth and

each remaining segment progressively smaller than one before. First 14 axial rings bear large medial nodes; macrospine on fifteenth segment rapidly tapering and relatively short. Opisthothorax short, consisting of three(?) segments and followed by small, button-like pygidium. Ornamentation consists of lightly developed reticulate network on interocular area and near midline on posterior portion on cephalic axis, strong venation on extraocular area, weak terrace lines on anterior and lateral border.

Discussion. The cephalon of this species (except for the ornamentation) resembles that of *Wanneria*, especially *Wanneria walcottana* (Wanner, 1901), more than it does that of *Olenellus*. However, an attached prothorax with a third macropleural segment and a fifteenth segment bearing a macrospine clearly precludes a *Wanneria* placement. *Olenellus brevoculus* Resser and Howell, 1938 displays short ocular lobes like those present on *O. truncatooculatus*, but exhibits metagenal spines and has genal spines that are advanced. The short ocular lobes on *Olenellus canadensis* Walcott, 1910 are directed more strongly backward, and the associated anterior glabellar lobe is located farther forward. *Olenellus fremonti* Walcott, 1910 also has short ocular lobes, but has advanced genal spines. *Olenellus arcuatus* Palmer, 1979 differs from *O. truncatooculatus* in having a genal angle drawn back beyond the neutral position of that of *O. truncatooculatus*, a glabella that is more constricted, and ocular lobes that are slightly longer.

Genus *Mummaspis* gen. nov.

Type species. Wanneria occidens Walcott, 1913.

Etymology. The genus is named after Mumm Peak, the peak rising immediately east of locality 61k.

Diagnosis. Genus exhibits usual Olenellidae characteristics, such as prothorax with third macropleural segment and macrospine on fifteenth segment. Cephalon has stronger than average curvature along front margin. Ocular lobes inclined steeply backward; anterior and lateral borders wide; genal spine flat, wide at base, short. Glabella exhibits less than usual constriction at level of posterior pair of glabellar furrows. Anterior glabellar lobe has greater relative length. Large occipital spine may or may not be present.

Discussion. At present this genus is known only from *Mummaspis occidens* (Walcott, 1913a) and *Mummaspis oblisooculatus* sp. nov. The holotype for *Wanneria occidens* was probably the only *Mummaspis* specimen in the 1912 part of Walcott's 61k collection, which was the only part available when he described what is here referred to as *Mummaspis occidens*. The holotype is a small cephalon, but clearly displays metagenal spines that are also present on larger cephala in the 1913 part of the collection. Spines of this type are not present in *Wanneria*, a genus that at most displays swellings at the metagenal spine positions. Walcott (1913a, p. 314) noted a "short occipital spine" on his specimen that is in fact of considerable size, and together with the metagenal spines, might have been seen as grounds for at least adding a question to the *Wanneria* assignment. Attached thoraxes on the 1913 specimens illustrated in this paper exhibit macropleural third segments and a large spine on the fifteenth axial ring. These and the other mentioned features warrant removal of this species from *Wanneria*.

Walcott (1910, Pl. 29, figs. 1, 5, 6) has figured several cephala from locality 1f, Silver Peak area, Nevada, which bear some resemblance to those of *Mummaspis*, especially in having a large occipital spine. These cephala appear in the same plate as specimens belonging to another genus, *Holmia*, and Walcott assigned all of the material to *Holmia rowei* sp. nov. Walcott's cephala in question have a relatively smaller, more posteriorly located anterior glabellar lobe, longer and narrower genal spines, and a narrower occipital spine (not adequately shown in Walcott's 1910 illustrations) rising from within the occipital ring, rather than emanating from its posterior margin. Resser and Howell (1938, p. 229) referred the material in Walcott's plate (loc. cit.) to their new genus, *Esmeraldina*, but, like Walcott, maintained that it all belonged to one species, *E. rowei*. Locality 1f also contained *Nevadia* on the same block with correctly identified *Holmia* parts, which is good evidence for placing at least a part of the collection in the *Nevadella* Zone.

The position of *M. occidens* immediately above the lower boundary of the *Bonnia-Olenellus* Zone (Fig. 3, GSC loc. 90571), and the position of *Mummaspis oblisooculatus* a short distance above *Laudonia bispinata* (GSC loc. 90578), provide a short range for the genus at the base of the zone. This range may eventually be extended upward (GSC loc. 90579), when more material is available to permit closer identification of the taxon presently listed as ?*Mummaspis oblisooculatus*.

Mummaspis occidens (Walcott, 1913)

Plate 9, figures 2–5, Plate 10, figures 1–5; Figure 6a

1913a *Wanneria occidens* Walcott, p. 314, Pl. 53, fig. 2.
1938 *Esmeraldina occidens* (Walcott); Resser and Howell, p. 229.

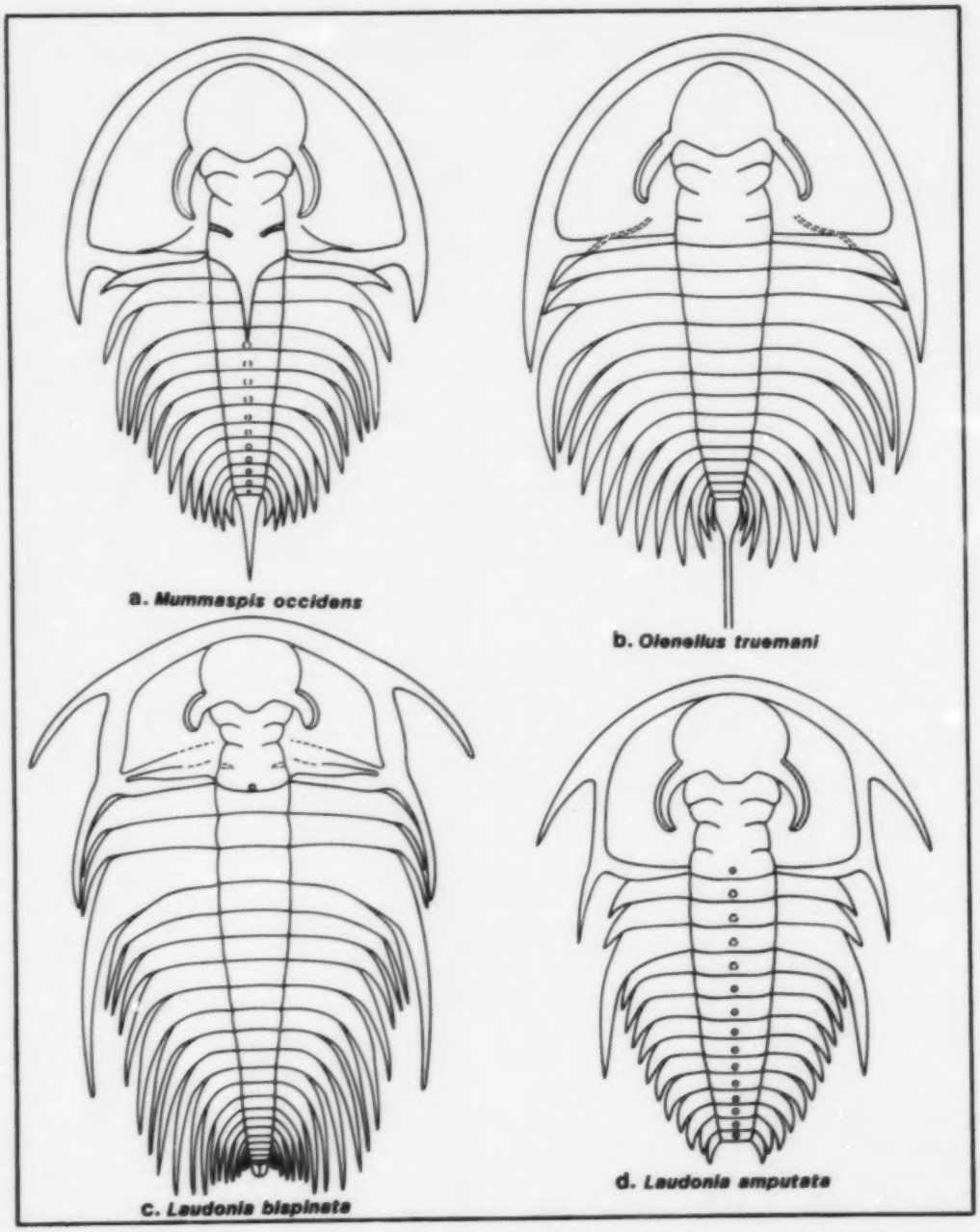


*Figure 6. Line drawings showing cephala with attached prothoraxes of a) **Mummaspis occidens** (Walcott, 1913) and b) **Olenellus truemani** Walcott, 1913. a dorsal exoskeleton of c) **Laudonia bispinata** Harrington, 1956, and a cephalon with incomplete thorax of d) **Laudonia amputata** sp. nov.*

Material. Eight cephala with lengths of 11.2 to 30.0 mm (exclusive of occipital spines) from locality 61k, four of which have partial thoraxes attached. Two cephala, 12.5 and 22.5 mm long, from GSC locality 90571.

Description. Cephalic outline is that of a half ellipse, front margin strongly curved, sides broadly curved. Anterior and lateral border uniformly wide, extending backward into short genal spines. Anterior glabellar lobe

(L4) long, broadly curved along front, and nearly touching anterior border furrow. Anterior pair of glabellar furrows (S3) chevron-shaped, joining across glabellar midline; second pair (S2) arcuate, average inclination is less strongly backward than similar parts on anterior pair; posterior pair (S1) straight and inclined strongly backward. Occipital furrow wide and deep along distal segments, medial segment obsolete. Occipital ring bears large spine. Posterior border transverse, expanding along proximal three quarters to incipient metagenal spine; inclined slightly forward along distal quarter. Ocular lobes directed strongly backward, terminating opposite midpoint on posterior pair of glabellar lobes or slightly farther back.

Hypostome has ovoid anterior lobe, wide (exsag.), flat anterior wings, wire-like anterior border, elongate, slit-like maculae. Posterior margin unknown (damaged).

Prothorax composed of 15 segments, third segment macropleural, fifteenth bears a large macrospine. Inner pleurae exhibit deep pleural furrows. Spines on anterior pair of pleurae short, on second pair intermediate, on third pair longest, remaining pairs each progressively shorter than preceding pair. Ornamentation consists of terrace lines on doublure of anterior and lateral border, reticulate network on gena and glabella, radial venation on internal moulds of gena, and nodes on first to fourteenth axial rings on prothorax.

Discussion. Cephala of *Mummaspis occidens* differ from those of *Mummapis oblisooculatus* sp. nov. in having an anterior glabellar lobe that is located farther back, possessing a large spine on the occipital ring, having small metagenal spines, and having genal spines that are located in a more anterior position. The thorax of *Mummaspis occidens* differs in having nodes on the axial rings and a shorter, wider macrospine on the fifteenth axial ring.

Mummaspis oblisooculatus sp. nov.

Plate 16, figures 4–7, Plate 17, figures 1–5;
Figure 5b

Etymology. Latin, *obliso,* sqeezed together, and Latin, *oculus,* eye, emphasizing the ocular lobes pressed close to (but not against) the glabella.

Material. Thirteen cephala with lengths of 2.1 to 18.0 mm from locality 61k, largest having prothorax attached. Three cephala from GSC locality 90578 with lengths of 18.0 to 30.5 mm. Two questionably assigned cephala are from GSC locality 90579.

Description. Cephalon has strong frontal curvature for an olenellid, sides broadly curved, total outline approaching subtriangular shape, length to width ratio is 11:20. Anterior glabellar lobe (L4) on cephala exceeds 13 mm in length, touches anterior border furrow, lobe broadly curved in front, sides having less curvature and starting to converge at contact with ocular lobes. Lateral margins of third and second pairs of glabellar lobes (L3, L2) form uniform, moderately convex curves with average directions that converge slightly in posterior direction. Posterior lobes (L1) longer (exsag.) than occipital ring. Anterior and second pairs of glabellar furrows (S3, S2) chevron-shaped, distal segments of furrows shallow, proximal segments deep and joined across midline by short, curved, connecting furrow. Posterior pair of glabellar furrows (S1) join to form broad, posteriorly directed curve. Occipital furrow broad and deep along distal quarter, obsolete along medial half. Ocular lobes inclined steeply backward, terminating opposite anterior third of posterior glabellar lobe. Palpebral lobes narrow; ocular furrow narrow, shallow. Anterior and lateral border uniformly wide; in cross-section, borders rise abruptly from gena, then broadly curve outward to cephalic margin. Posterior border initially transverse or inclined slightly backward, gradually widening distally, then curving back to merge into broad (at base), short genal spine. Metagenal ridge narrow, low, traceable from behind ocular lobes to point where it joins posterior border two thirds from proximal end of border, ridge faintly continuing at angle across border.

Prothorax bears very long, falcate pleural spines. Width (exsag.) of third (macropleural) pair of inner pleurae between a quarter and a fifth wider than adjacent inner pleurae. Macrospine on fifteenth segment narrows rapidly from base, then continues at nearly uniform, narrow width, total length at least three fifths that of remaining prothorax. Ornamentation on extraocular area consists of low ridges of anastomosing venation on extraocular area; ridges inclined back at low angle. Polygonal network visible between metagenal ridge and posterior border furrow. Occipital ring bears small node; nodes lacking on axial rings of prothorax.

Discussion. The many similarities between *Mummaspis occidens* and *Mummaspis oblisooculatus,* and their relative stratigraphic position strongly suggests the latter evolved from the former. If so, *M. oblisooculatus* represents an example of convergence toward *Olenellus* by losing its broad occipital spine and developing wider (trans.) pleurae relative to the width of the thoracic axis. The glabella of a (?)younger olenellid, *Olenellus schofieldi* Best, 1952, has a general outline similar to that of *M. oblisooculatus* and *M. occidens,* and similar ocular lobes as well. However, *O. schofieldi* has a broader

curvature along the front margin of the cephalon, narrower cephalic border, and a pronounced macropleural segment that is quite different. The glabella of *Olenellus hermani* Kindle and Tasch, 1948 has small ocular lobes projecting steeply backward from a large anterior lobe. However, *O. hermani* exhibits a spine on the anterior glabellar lobe and is known only from incomplete and poorly preserved material. Fragments of *Olenellus canadensis*? Walcott, 1910 from the Peyto Formation, Mount Bosworth, Alberta (see especially Walcott, 1910, Pl. 38, figs. 4, 5) have a glabella similar to that of *O. oblisooculatus*, but are too incomplete for a critical comparison.

Genus *Gabriellus* gen. nov.

Type species. Gabriellus lanceatus gen. et sp. nov.

Etymology. The name, altered for euphonic reasons, honours H. Gabrielse, who began a long and productive geological career in the Dease Lake area, Cassiar Mountains, British Columbia. There (Fritz, 1978b, section 2, unit 4) Gabrielse found (GSC locs. 20121, 20122, 25012) the first described species of this genus (Whittington, 1989, Figs. 21, 22, 26), a species that has yet to be named.

Diagnosis. Genus resembles *Olenellus*, but has narrower, more pointed anterior glabellar lobe, ocular lobes that remain close to axial furrows, glabella that tapers forward or is parallel-sided instead of exhibiting moderate hour-glass configuration, and borders that are narrower than those on most species of *Olenellus*. Prothorax has 15 segments and wide axis bordered by short (tr.) inner pleurae. Opisthothorax known from one species to have two segments. Pygidium narrow, elongate, nearly smooth.

Discussion. The above diagnosis is based in part on *Gabriellus lanceatus* and in part upon the mentioned species of *Gabriellus* from the Cassiar Mountains described by Whittington (1989) as "Olenelloid gen. et sp. ind." Additional data on the Cassiar species can be found in an unpublished Ph.D. thesis by Best submitted at Princeton University in 1959. I am in the process of describing this species from my own GSC collections and from those made by Gabrielse.

Gabriellus lanceatus gen. et sp. nov.

Plate 6, figure 5(?), Plate 17, figure 6;
Figure 5d

Etymology. Latin, *lancea*, a light spear, referring to the lance-head outline of the glabella.

Material. One cephalon in collection 61k, 27.5 mm long, and one tentatively assigned thorax 63.0 mm long (excluding macrospine). Two cephala with lengths of 18.0 and 30.0 mm, from GSC locality 90579.

Description. Cephalon length slightly greater than half of width. Anterior and lateral border uniformly narrow except for widening close to genal angles; border extends into narrow spine that is nine twentieths length of cephalon. Sides of glabella converging forward, broadly convex. Anterior lobe (L4) long, narrow, bullet-shaped, touching anterior border furrow. Anterior glabellar furrows (S3) chevron-shaped, long proximal segments inclined steeply backward, joined by short transverse segment crossing axial midline, all segments of furrows are of equal depth. Medial pair of glabellar furrows (S2) curved, very shallow distally, deepening inward to medium depth, abruptly terminating well away from axial midline. Posterior pair (S1) nearly straight, inclined back at slightly greater angle than average inclination of medial pair. Distal segments of occipital furrow wider and deeper than glabellar furrows, medial five ninths obsolete. Occipital ring has node on posterior margin. Ocular lobes inclined backward at a steep angle, maintaining contact with axial furrow where furrow borders lateral margin of anterior glabellar lobes, terminating just ahead of distal ends of occipital furrow. Ocular furrow of medium depth, wide; palpebral lobes narrow. Proximal half of posterior border inclined moderately forward, expanding distally to attain medium width; distal half directed forward at slightly greater angle, of uniform width that is three-quarters of maximum width of proximal half. Weak metagenal ridge visible behind ocular lobe, ridge merges at low angle with posterior border near middle of proximal half. No metagenal spine visible. Ornamentation consists of radial, anastomosing venation on gena.

Tentatively assigned prothorax is composed of 15(?) segments, axis remarkably wide (tr.) and pleurae remarkably short (tr.). Inner pleurae have nearly square outline, anterolateral margin of pleurae inclined posteriorly at an abrupt angle into rapidly tapering spines with narrow tips. Pleural furrows wide proximally, rapidly narrowing distally. Anterior band on third pleura considerably wider than others. Macrospine on fifteenth axial ring displays rapidly tapering base (remainder not preserved). Axial rings each uniformly smaller than one in front. Ornamentation consists of lightly defined, polygonal network on axial rings and pleurae and node on posterior margin of axial rings.

Discussion. The single available cephalon from locality 61k matches those found in the Mumm Peak section at GSC locality 90579, located approximately 110 m above

the one occurrence of *Laudonia*. A similar occurrence of a second species of *Gabriellus* above *Laudonia* in the Cassiar Mountains suggests that the genus occupies strata of approximately the same age in the two areas. As only one thorax is known from the Mount Robson area, and that is in loose blocks in collection 61k, there is no assurance that it is conspecific with *Gabriellus lanceatus*. The thorax does compare closely with those from the Cassiar Mountains, therefore its generic assignment is not questioned.

Family Nevadiidae Hupé, 1953a

Genus *Nevadia* Walcott, 1910

1910 *Nevadia* Walcott, p. 256.
1915 *Nevadia* Walcott; Swinnerton, p. 495, 456.
1928 *Nevadia* Walcott; Resser, p. 5.
1932 *Nevadia* Walcott; Poulsen, p. 36.
1936 *Nevadia* Walcott; Raw, p. 243, 244, 249, 250.
1937 *Nevadia* Walcott; Raw, p. 577, 578.
1937 *Nevadia* Walcott; Lake, p. 247.
1953a *Nevadia* Walcott; Hupé, p. 124.
1953b *Nevadia* Walcott; Hupé, p. 73.
1959 *Nevadia* Walcott; Poulsen, p. O196.
1979 *Nevadia* Walcott; Repina, p. 19.
1987 *Nevadia* Walcott; McMenamin, p. 744.

Type species. Nevadia weeksi Walcott, 1910.

Diagnosis. Cephalon wide for Olenellida, semielliptical in outline, broadly curved in transverse section, local relief low. In plan view, glabella cone-shaped, sides straight or slightly concave, front narrow and strongly curved, terminating well back from anterior border. Ocular lobe of long to medial length, delineating narrow interocular area from very wide extraocular area. Posterior border inclined backward at a shallow to large angle. Thorax wide (tr.), 27 segments on only described species with a complete thorax, axis relatively narrow. Successive pleurae in anterior portion of thorax diminish in size gradually toward rear, pleural spines long and falcate; posterior portion has abruptly narrower and shorter pleurae. Pygidium narrow and short.

Discussion. The concept of *Nevadia* has generally evolved around a composite illustration assembled by Walcott in 1910, which was based on three specimens. The thorax and pygidium of the composite belong to one specimen (Walcott, 1910, Pl. 23, fig. 1). To this has been added an inked outline of a cephalon based mainly on a second specimen (op. cit., Pl. 23, fig. 3). The first two specimens exhibit strong transverse distortion (see also Nelson and Durham, 1966, Pl. 2, fig. 8 for nearly identical distorted cephalon of *N. weeksi*). The third specimen (op. cit., Pl. 23, fig. 2) is smaller and was given far less consideration in the construction. All three specimens are reported to have come from locality 1f, and all are preserved in a similar siltstone matrix.

A constructive change in the concept of *Nevadia* emanates from Whittington's (1989) designation of Walcott's third (less distorted) specimen as lectotype for the type species. Using the lectotype as principle reference, *Nevadia* can be said to differ from *Nevadella* in having a wider cephalon, shorter glabella, narrower anterior and lateral borders, a more posteriorly inclined posterior border, and longer ocular lobes. Described species included in *Nevadia* are *N. addyensis* Okulitch, 1951, *N. bacculenta* (Fritz, 1972b), *N. cartlandi* (Walcott, 1910), *N.? crosbyi* (Raw *in* Walcott, 1910), *N. parvoconica* sp. nov., and *N. weeksi* Walcott, 1910. In his discussion of *Nevadia*, McMenamin (1987, p. 744) has emphasized the length of ocular lobes as a tool for separating "long-eyed" species of *Nevadia* from "short-eyed" species of *Nevadella*. I prefer to use all five features mentioned above to separate the two genera. I would, for instance, favour placing *Nevadia ovatis* McMenamin, 1987 in *Nevadella* rather than *Nevadia*, as it meets only one of the four mentioned criteria (ocular lobes) for placing it in *Nevadia*.

Whittington (1989, p. 124) suggested that the features of *Nevadia* and *Nevadella* overlap to such a degree that *Nevadella* should be considered a junior synonym of *Nevadia*. At the very least, I favour a delay in acting on this suggestion. Nevadiids described in the present paper fall into two morphological groups (see Fig. 7), and those placed under *Nevadia* are older than those under *Nevadella*. This suggests, at least for the present, that there is both biostratigraphic and taxonomic benefit in maintaining two genera.

As implied above, *Nevadella* is the closest genus to *Nevadia*. *Judomia* resembles *Nevadia*, but has a relatively larger, parallel-sided glabella, ocular lobes that attach farther forward on the glabella, and a narrower (tr.) extraocular area. Whittington has suggested that *Buenellus* Blaker, 1988 might be included in *Nevadia*. That genus differs from *Nevadia* in having a much wider glabella, wider interocular area, narrower extraocular area, and much shorter pleural spines on the thorax. *Callavia* is a genus that has been wrongly but consistently used for *Nevadia* or *Nevadella* in many of the older Canadian reports. Features that differentiate *Callavia* from the last two genera are the same as those mentioned

for separating *Nevadia* from *Buenellus*. In addition, *Callavia* has a large occipital spine and exhibits metagenal spines.

Nevadia weeksi Walcott, 1910

Plate 1, figures 1–11, Plate 2, figures 1–6; Figure 7a

1910 *Nevadia weeksi* Walcott, p. 257, Figs. 14, 15, Pl. 23, figs. 1–7, Pl. 44, fig. 1.
1916 *Nevadia weeksi* (Walcott); Walcott, Pl. 14, fig. 1.
1952 *Nevadia weeksi* Walcott; Tasch, p. 485, 487, Fig. 1, G.
1959 *Nevadia weeksi* Walcott; Poulsen, p. O196, Fig. 135, no. 3.
1989 *Nevadia weeksi* Walcott; Whittington, p. 122, Figs. 23, 39–44, 47, 49, 52, 53.

Material. Twelve cephala, 5.0 mm to 30.0 mm long, from GSC localities 87898 (7) and 87899 (5).

Description. Cephalon very wide, in front view upper surface broadly convex with increasing curvature near distal margins, ocular lobes and axis abruptly raised for nevadiid. Glabella cone-shaped, ending in blunt point, terminating well back from anterior border, in side view front rises abruptly above preglabellar field. Three pairs of glabellar furrows (S1–S3) inclined backward at approximately same angle, wide and deep near axial furrow, rapidly shallowing inward, joining across midline by broad, shallow furrow. Occipital furrow wider and deeper than glabellar furrows, inclined less steeply backward, extinct along medial half. In side view occipital ring rises from front to back, ring bears node near posterior margin. Ocular lobes straight and inclined steeply backward along initial third, distal two thirds broadly and evenly curved, distal ends directed inward, terminating close to glabella and opposite anterior third of occipitial ring; raised platform underlies area once occupied by visual surface. Interocular area rather narrow, extraocular area exceptionally wide (tr.). Anterior and lateral borders of uniform, medium width, abruptly raised above shallow border furrow, broadly curved in cross-section, tilted outward. Posterior border narrow (exsag.) and low, inclined backward at a steep angle on small and medium specimens, moderately backward on large specimens, expanding near base of flat genal spine. Extraocular area marked by wide, anastomosing, radiating venation; venation on "peeled areas" narrower, strongly raised. Axis bears crude polygonal network.

Discussion. The Mount Robson specimens of *Nevadia weeksi* (preserved in limestone) compare as closely as can be expected with the lectotype (preserved in siltstone). Whittington (1989, p. 123) writes that a ". . . preglabellar ridge may extend between border and frontal glabellar lobe." This "ridge" is probably a secondary, tectonic feature, as even the lectotype is moderately distorted. No preglabellar ridge is visible on Walcott's illustrated topotype specimens, nor is one visible on the Mount Robson material. The exceptionally wide extraocular area with equally exceptionally strong venation, and long ocular lobes terminating close to the glabella, differentiate this species from others that have been placed under *Nevadia*.

Nevadia parvoconica sp. nov.

Plate 2, figures 7–9; Figure 7b

Etymology. Latin, *parvus*, small, and *conus*, cone-shaped, referring to the small, cone-shaped glabella.

Material. One cephalon, 13 mm long, from GSC locality 90563.

Description. Cephalon has length to width ratio of 1:2. Glabella small, low, sides slightly concave, converging moderately forward to second pair of glabellar furrows (S2), then only slightly forward before finally turning inward to very low, broadly pointed front. Glabella terminates well back from anterior border. Glabella preceded by, but not connected to, short ridge that originates on anterior margin of preglabellar field, crosses anterior border furrow, and merges with posterior margin of anterior border. Three pairs of glabellar furrows visible (S1-S3), all inclined backward at approximately same angle, all very shallow, anterior pair exceedingly shallow, all faintly joined across axial midline. Occipital furrow consists of two narrow, slightly arcuate, moderately inclined segments; medial half of furrow obsolete. Interocular area flat, inclined moderately inward; at level of maximum width, ratio of width of area to adjacent glabella is 3:5. Ocular lobes uniformly curved, tilted inward, terminating opposite midpoint on lateral margin of posterior glabellar lobe. Anterior and lateral borders of uniform width except for broadening near base of genal spine; anterior border tilted slightly forward, lateral border outward, increasingly so with decreasing distance to genal spine. Anterior and lateral border furrows shallow, containing row of very small pits. Proximal three-quarters of posterior border expanding only slightly distally, nearly straight, directed moderately backward; distal quarter slightly offset, widening toward

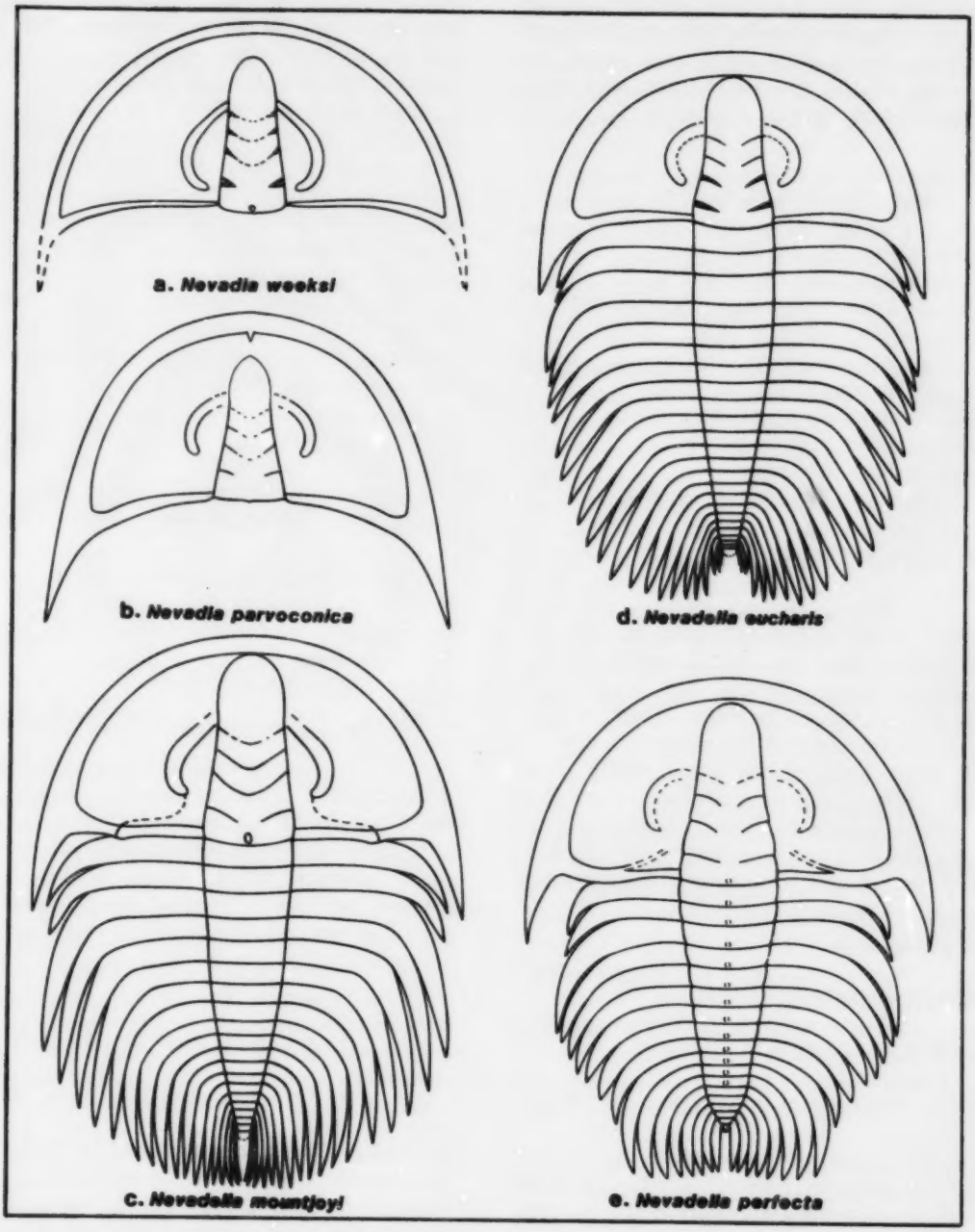


Figure 7. Line drawings showing cephala of a) Nevadia weeksi Walcott, 1910 and b) Nevadia parvoconica sp. nov., and dorsal exoskeletons of c) Nevadella mountjoyi sp. nov., d) Nevadella eucharis (Walcott, 1913), and e) Nevadella perfecta (Walcott, 1913).

genal spine. Genal spine wide at base, length half as long as cephalon. Cephalon nearly smooth, terrace lines on anterior and lateral borders and on genal spine. Presence or absence of occipital node unknown (broken).

Discussion. Nevadia parvoconica most closely resembles *N. bacculenta* (Fritz, 1972b). Both have ocular lobes of medium length and a posterior border that is inclined backward at a steep angle. *Nevadia parvoconica* differs

from *N. bacculenta* in having a longer, narrower glabella with a much lower anterior glabellar lobe, no continuous preglabellar ridge, no medial recurvature along the posterior margin of the anterior border, and much shallower occipital and glabellar furrows.

Genus *Nevadella* Raw, 1936

1936 *Nevadella* Raw, p. 243-250.
1937 *Nevadella* Raw; Raw, p. 578.
1939 *Nevadella* Raw; Whitehouse, 1939, p. 191.
1953a *Nevadella* Raw; Hupé, p. 124.
1953b *Nevadella* Raw; Hupé, p. 73.
1959 *Nevadella* Raw; Poulsen, p. O196.
1972b *Nevadella* Raw; Fritz, p. 22.
1979 *Nevadella* Raw; Repina, p. 19.
1988 *Nevadella* Raw; Blaker, p. 35.
1989 *Nevadella* Raw; Whittington, p. 124, 125.

Type species. Callavia eucharis Walcott, 1913.

Discussion. The generic diagnosis by Fritz (1972a) is followed in this paper. The present study of *Nevadella eucharis, Nevadella mountjoyi,* and *Nevadella perfecta* shows that, at least for these species, there is a moderate macropleural development of the third thoracic segment. Heretofore, it was claimed that the genus lacked such a development (Whitehouse, 1936; Hupé, 1953b; Fritz, 1972b; Blaker, 1988). The three species within the genus that are presently known to have complete thoraxes display 17, 19, and 23 thoracic segments. *Nevadia* is the genus that most closely resembles *Nevadella* (see discussion under *Nevadia*).

Nevadella eucharis (Walcott, 1913)

Plate 4, figures 1-3; Figure 7d

1913 *Callavia eucharis* Walcott, 1913a, p. 315, Pl. 53, fig. 1.
1936 *Nevadella eucharis* (Walcott); Raw, p. 249, 250.
1959 *Nevadella eucharis* (Walcott); Poulsen, p. O196.
1960 *Nevadella eucharis* (Walcott); Best *in* Kielan, p. 89.
1972 *Nevadella eucharis* (Walcott); Fritz, 1972b, p. 22.

Material. One complete specimen in the collection from locality 61k, total length 37.0 mm, length of cephalon 13.2 mm. Three cephala from GSC locality 90566, one 5.5 mm long and two both 14.0 mm long.

Description. Cephalon has length to width ratio of 7:15, broadly curved along front margin, strongest curvature at anterolateral margin, genal angle drawn slightly backward. Glabella tapered forward, reaching or nearly reaching anterior border furrow, sides broadly concave. Anterior and second pair of glabellar lobes (L3, L2) equal in length (exsag.), posterior pair (L1) one third longer. Glabellar furrows inclined backward, each pair slightly more so than preceding pair, anterior pair (S3) shallow, remaining pairs and distal segments of occipital furrow each progressively deeper than pair in front. Ocular lobes directed moderately out, curving back to terminate opposite halfway point on lateral margin of posterior glabellar lobe. Anterior and lateral border wide, of uniform width. Posterior border initially transverse, then uniformly and broadly curved gently backward to short genal spine with wide base.

Thorax composed of 23 segments, inner pleura on third segment one quarter wider (exsag.) than adjacent inner pleura. Pleural furrows wide (exsag.), pleural spines falcate. Pygidium small, short, poorly known.

Discussion. Raw (1936, p. 249) questioned the validity of this species, and both Best (*in* Kielan, 1960, p. 89) and Fritz (1972b, p. 22) placed *Nevadella perfecta* under *Nevadella eucharis*. This was done despite Walcott's having illustrated a paratype of *N. perfecta* bearing 17 thoracic segments, and a holotype of *N. eucharis* bearing 23. The former type is only slightly smaller than the latter. The following features on *N. eucharis* differentiate it from *N. perfecta*: cephalon wider and more broadly curved along front margin, ocular lobes initially directed more strongly outward, metagenal ridge obsolete, genal spine located farther back, pleural furrows much wider (exsag.), pleural spines longer and with narrower tips, thorax with 23 rather than 17 thoracic segments.

Nevadella mountjoyi sp. nov.

Plate 3, figures 1-6; Figure 7c

Etymology. The species is named for E.W. Mountjoy, a prominent Cordilleran structural geologist and stratigrapher. Mountjoy (1980) mapped the Mount Robson area, and generously shared his knowledge with me there in 1973.

Material. Nineteen cephala from GSC localities 90564 (4) and 90565 (15), three of which have thoraxes attached. Cephalic length between 5.5 and approximately 28 mm.

Description. Cephalic outline semicircular, length slightly greater than width. Glabella converging slightly and uniformly in forward direction, front well rounded and

touching, but not displacing anterior border furrow. Three pairs of glabellar furrows, anterior pair (S3) inclined moderately backward, shallow, medial pair (S2) has equal inclination, of moderate depth, posterior pair (S1) more steeply inclined and still deeper; posterior two pairs joined across axial midline, anterior pair faintly joined. Occipital furrow well incised at distal ends, narrowing and shallowing inward and curving back, medial four tenths obsolete. Elongate node present on occipital ring. Ocular lobes directed rather strongly backward, rapidly curving near ends that terminate approximately opposite midpoint on lateral margin of posterior glabellar lobe (L1). Maximum width of interocular area one third width of glabella at same level (tr.). Anterior and lateral borders of uniform, medium width, abruptly rising from border furrow. Anterior and lateral border furrows uniformly deep throughout, single row of small pits present near outer margin. Posterior border directed outward and slightly backward along proximal three-quarters, width nearly uniform; distal quarter diverted slightly at start where intersected by metagenal ridge emanating from near base of ocular lobe.

Thorax composed of 19 segments, macropleural third segment has inner pleural width (exsag.) that is five fourths that of adjacent inner pleurae. Pleural spines falcate, those on anterior two pleurae proportionally smallest. Shape and size of pygidium unknown (poorly preserved). Ornamentation consists of radial venation on extraocular area.

Discussion. The cephalon of *Nevadella mountjoyi* resembles those of *Nevadella eucharis* and *Nevadella perfecta*, but differs in having glabellar furrows that clearly join across the axial midline on large cephala, an anterior lobe that terminates slightly farther forward, ocular lobes that are directed more strongly backward, and a narrower anterior and lateral border with an inner margin that rises abruptly above the adjacent border furrow. *Nevadella mountjoyi* has 19 thoracic segments as opposed to 23 on *N. eucharis* and 17 on *N. perfecta*.

Nevadella perfecta (Walcott, 1913)

Plate 4, figures 4–6, Plate 5, figures 1–5; Figure 7e

1913a *Callavia perfecta* Walcott, p. 315, Pl. 53, figs. 3, 4, 5?
1936 *Nevadella perfecta*? (Walcott); Raw, p. 249.
1960 *Nevadella eucharis* (Walcott); Best *in* Kielan, p. 89.
1972b *Nevadella eucharis* (Walcott); Fritz, p. 22.

Material. Twenty-five cephala from locality 61k with lengths from 2.9 to 16.2 mm; three of the cephala from locality 61k have thoraxes attached. Seventy-three cephala with lengths from 4.0 to 26.0 mm from GSC localities 90567 (44), 90568 (13), 90569 (9), 90570 (7).

Description. Cephalic outline is semicircular, slightly wider than long. Glabella tapers forward, sides slightly concave, terminating short distance before reaching anterior border furrow. Anterior and second pair of glabellar lobes (L3, L2) approximately equal in length (exsag.); posterior pair (L1) longer. Anterior pair of glabellar furrows (S3) shallow, remaining two pairs and distal segments of occipital furrow each progressively deeper than pair in front. Medial and posterior pairs (S2, S1) slightly arcuate, all glabellar furrows join across axial midline on small- and medium-sized cephala; on large cephala, pairs are separate or joined by broad, shallow furrow (deeper on cephala subjected to greater compaction). Ocular lobes directed strongly out, terminating opposite or slightly ahead of midpoint on lateral margin of posterior glabellar lobe. Metagenal ridge weak, intersecting anterior margin of posterior border at five-eights point from proximal end of border. Posterior border generally transverse or inclined slightly backward, distally wider from point where intersected by metagenal ridge.

Thorax composed of 17 segments. Spines on posterior 14 pleurae falcate, wide, retaining close proximity to adjacent spines along most of length; spines on anterior two pairs shorter. Width (exsag.) of inner pleurae on third segment one third greater than that of adjacent pleurae; third pair of pleural spines only slightly longer than next posterior pair. Pygidium poorly known (not clearly exposed). Ornamentation consists of terrace lines on doublure of anterior and lateral cephalic borders, single row of very small pits in anterior and lateral border furrows, venation on extraocular area, small occipital node present. Each axial ring on at least anterior and medial part of thorax bears a node.

Discussion. Comparisons of *Nevadella perfecta* with *Nevadella eucharis* and *Nevadella mountjoyi* are given under the latter two species.

Family Wanneriidae Hupé, 1953a

Genus *Laudonia* Harrington, 1956

1956 *Laudonia* Harrington, 1956, p. 60.
1959 *Laudonia* Harrington; Poulsen, 1959, p. O192.
1972 *Laudonia* Harrington; Fritz, 1972b, p. 27.

Type species. ***Laudonia bispinata*** Harrington, 1956.

Diagnosis. Cephala semiquadrate in outline, genal spines advanced, metagenal spines large and located in expected olenellid genal spine position. Glabella strongly hourglass-shaped, anterior glabellar lobe short (sag.), high, anterior margin in contact or nearly so with anterior border furrow. Thorax only completely known from one species, containing 22 segments, third segment macropleural. Pygidium small, bilobate. Exoskeleton marked by reticulate network.

Remarks. ***Laudonia bispinata*** Harrington, 1956 and ***Laudonia*****?** ***mexicana*** (Lochman, 1952) are the only described species to date. The present paper adds *L. amputata* sp. nov. and provides the first description of a *Laudonia* thoracic region. ***Bristolia*** closely resembles ***Laudonia***; however, the cephalon lacks a second (metagenal) pair of large cephalic spines and a reticulate ornamentation. The prothorax of ***Bristolia*** has 15 segments, exceptionally large pleurae on the third segment, and a macrospine on the last segment. ***Laudonia*****?** sp. 1 Fritz, 1972b is a species that should be placed under ***Bristolia***.

Laudonia bispinata Harrington, 1956

Plate 12, figures 4–8, Plate 13, figures 1–8, Plate 14, figures 1, 2; Figure 6c

1956 *Laudonia bispinata* Harrington, p. 60, Pl. 15, figs. 4, 5.

1959 Laudonia bispinata Harrington; Poulsen, 1959, p. O192, Fig. 134.

Material. Thirteen cephala from locality 61k with lengths of 2.0 to 25.0 mm, two of which have thoraxes attached. Eleven cephala from GSC localities 87891 (1) and 90577 (10) with lengths of 4.5 to 9.5 mm.

Description. Cephalon subquadrate, length to width ratio (exclusive of spines) is 11:20. Anterior margin of cephalon broadly curved, same curvature continues along proximal half of advanced genal spines, curvature along remainder of spines same or curved more strongly backward. Cephalic margins between genal and metagenal spines nearly straight and slightly diverging backward. Anterior glabellar lobe considerably wider than remainder of glabella, short (sag.), anterior margin broadly curved, flush with anterior border furrow; lobe strongly curved at anterolateral margins. Proximal parts of anterior two pairs of glabellar lobes (L2, L3) approximately equal in length (exsag.), second pair (L2) on some cephala bluntly pointed distally. Glabellar furrows deep, anterior pair (S3) chevron-shaped, joined across axial midline, medial pair (S2) arcuate, average inclination is slightly backward, posterior pair nearly straight and inclined more strongly backward. Distal ends of occipital furrow wide and deep, medial three sevenths effaced. Small node present on posterior margin of occipital ring. Ocular lobes very short; ocular furrow narrow, well incised; palpebral lobe of medium width, raised, tilted inward. Length (exsag.) of posterior pair of glabellar lobes approximately equals that of occipital ring. Anterior and lateral borders very wide, especially so near base of genal spines. Posterior border directed outward and slightly backward, expanding distally; near metagenal spine posterior margin of border redirected slightly forward to outline shallow cusp. Metagenal ridge wide, originating at low nodes opposite posterior (L1) glabellar lobes, inclined outward and slightly backward, straight, narrowing (exsag.) distally, directed into and merging with metagenal spine. Thread-like ridge originating near distal ends of posterior glabellar furrows, bisecting metagenal ridge and metagenal spine. Genal and metagenal spines of approximately equal strength and length, genal spine directed much more strongly outward; anterior half of metagenal spines diverge outward more strongly than cephalic lateral borders, posterior half of spines curve backward so that tips are directed slightly inward.

Thorax consists of 22 segments and is followed by small, bifurcating pygidium without border. Pleurae on anterior two segments equal in size and shape; maximum width (exsag.) of third inner pleura twice as wide as either of two anterior inner pleurae; anterolateral corner of third pleura strongly squared, spine large and long. Remaining 19 thoracic pleurae each smaller than preceding pleura. Exoskeleton covered by polygonal network, strongest development is on outer surface. Terrace lines present on doublure of cephalic spines and borders.

Discussion. ***Laudonia bispinata*** differs from ***Laudonia amputata*** in having a wider cephalon, shorter ocular lobes, and a relatively smaller glabella with greater constriction at the level of the posterior glabellar furrows. The thorax of *L. bispinata* is relatively wider and the pleural spines longer.

Laudonia amputata sp. nov.

Plate 11, figures 1–5, Plate 12, figures 1–3; Figure 6d

Etymology. Latin, ***amputata***, to lop off, amputate, referring to short (tr.) pleurae (both inner pleural portion and spine) on thorax.

Material. Five cephala from locality 61k with lengths of 12 to 38 mm, three of which have partial thoraxes attached. *Laudonia amputata* and *Olenellus muralensis* are the only trilobite species from locality 61k not found during the summers of 1971 and 1973. As the genus *Laudonia* is only known from the lower part of the *Bonnia–Olenellus* Zone, it is assumed that *L. amputata* in the 61k collection came from that part of the section in the Mount Robson area.

Description. Medium-sized cephala have length to width ratio (exclusive of spines) of 6:8, larger-sized have ratio of nearly 5:8. Frontal margin evenly curved between genal spines; sides straight and slightly diverging backward between genal and metagenal spines. Anterior glabellar lobe (L4) moderately curved along front, touching anterior border furrow. Anterior pair of glabellar lobes (L3) approximately as long (exsag.) as medial pair (L2) and only slightly wider (tr.); posterior pair (L1) approximately same length as occipital ring. Anterior pair of glabellar furrows (S3) chevron-shaped, joining across axial midline, medial pair (S2) arcuate and inclined slightly backward, posterior pair (S1) broadly curved and inclined somewhat more steeply backward. Distal quarter of occipital furrow wide and deep, medial half obsolete. Ocular lobes directed strongly backward, uniformly curved, terminating opposite point on distal margin of posterior glabellar lobe that is three-quarters of distance above base of lobe. Ocular furrow narrow, distinct; palpebral lobe only slightly wider. Genal spines much wider at base than metagenal spines, directed much more strongly outward; metagenal spines inclined steeply backward. Metagenal ridge poorly defined, narrow (exsag.), broadly curved, becoming obsolete before reaching base of metagenal spine. Posterior border weakly defined by shallow, border furrow; border directed outward and slightly backward except for short, distal segment that is inclined forward.

Thorax contains at least 14 segments (incomplete); inner pleurae short (tr.), sharply bent at anterolateral position where merging with short, steeply inclined pleural spines. Macropleural third pair of pleurae turn abruptly at anterolateral margin and extend into long pleural spines. Thoracic rings and occipital ring each bear low node. Exoskeleton covered with polygonal network.

Discussion. See discussion under *Laudonia bispinata* for a comparison with that species.

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PLATES 1-17

PLATE 1

Figures 1–11. *Nevadia weeksi* Walcott, 1910.

1. Cephalic internal mould, x5.9, GSC 98977, GSC loc. 87899.
2. Latex cast from external mould, x5.9, GSC 98978, GSC loc. 87899.
3. Latex cast from external mould, x5.9, GSC 98979, GSC loc. 87899.
4–6. Cephalic internal mould, plan, front, and side views, x5.9, GSC 98980, GSC loc. 87898.
7. Cephalic internal mould, x5.9, GSC 98981, GSC loc. 87898.
8. Cephalic internal mould, x5.9, GSC 98982, GSC loc. 87898.
9, 10. Cephalic internal mould, plan and front views, x5.9, GSC 98983, GSC loc. 87898.
11. Cephalic internal mould, x3.3, GSC 98984, GSC loc. 87898.

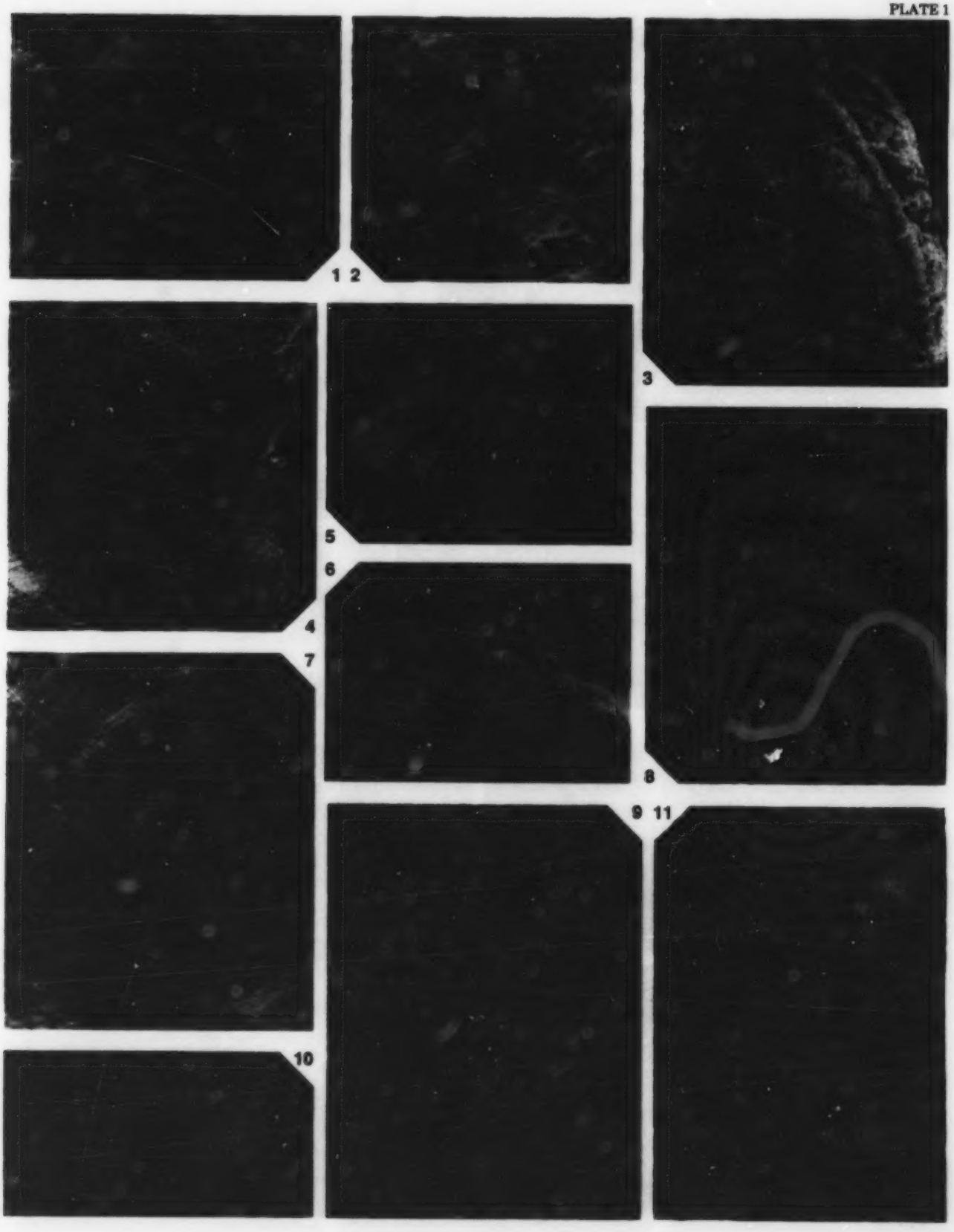
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PLATE 2

Figures 1–6. *Nevadia weeksi* Walcott, 1910.

1. Cephalic internal mould, x3.0, GSC 98985, GSC loc. 87898.
2–4. Cephalic internal mould, plan, side, and front views, x2.1, GSC 98986, GSC loc. 87898.
5, 6. Enlargement (x10) of cephalon shown in Plate 2, figures 2-4. Ornamentation on extraocular surface of gena near posterior third of ocular lobe (fig. 5), and opposite distal end of ocular lobe (fig. 6).

Figures 7–9. *Nevadia parvoconica* sp. nov. Cephalon in plan, front, and side views, x4.5, GSC 98987, GSC loc. 90563.

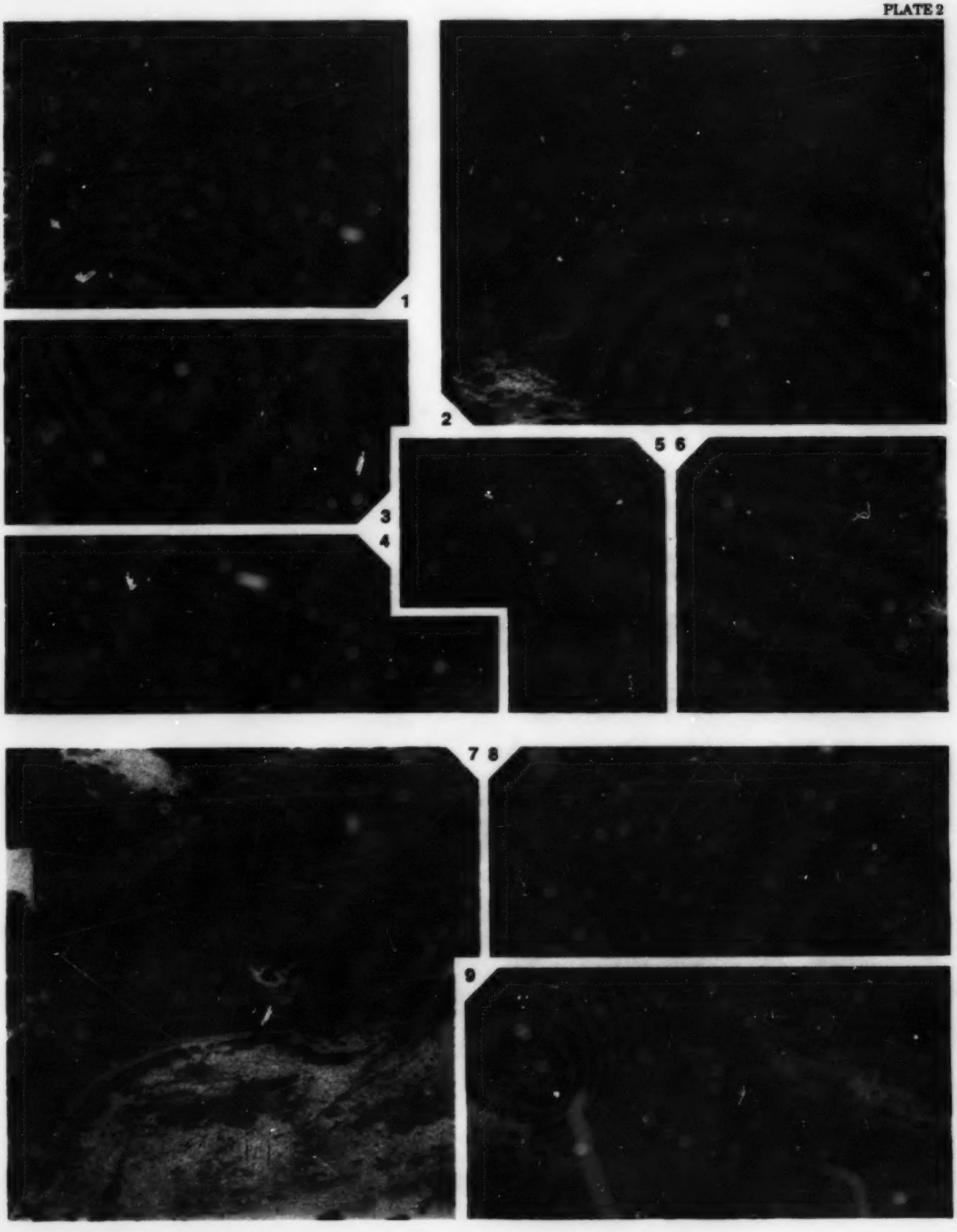
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PLATE 3

Figures 1–6. *Nevadella mountjoyi* sp. nov.

1. Latex cast of external mould, x6.0, GSC 98988, GSC loc. 90565.
2. Internal mould of partial exoskeleton, x6.0, GSC 98989, GSC loc. 90565.
3. Internal cephalic mould, x3.1, GSC 98990, GSC loc. 90565.
4. Latex cast of external mould of exoskeleton, x3.1, GSC 98991, GSC loc. 90564.
5. Latex cast from external cephalic mould, x2.9, GSC 98992, GSC loc. 90564.
6. Internal cephalic mould, x2.7, GSC 98993, GSC loc. 90565.

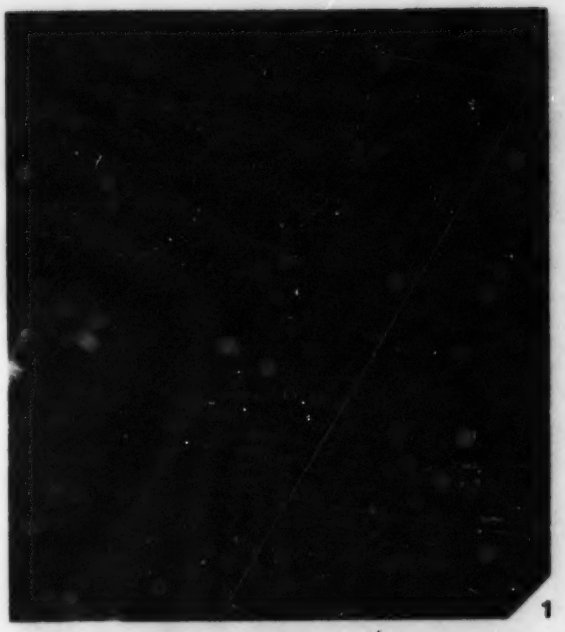

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PLATE 4

Figures 1–3. *Nevadella eucharis* (Walcott, 1913).

1. Two internal cephalic moulds, x4.4, GSC 98994 (left), GSC 98995 (right), GSC loc. 90566.
2. Latex cast of external cephalic mould, x5.9, GSC 98996, GSC loc. 90566.
3. Silicon replica of holotype, internal mould, x3.0, USNM no. 60079, locality 61k.

Figures 4–6. *Nevadella perfecta* (Walcott, 1913).

4. Internal cephalic mould, x6.2, GSC 98997, GSC loc. 90567.
5. Internal cephalic mould, x4.5, GSC 98998, GSC loc. 90567.
6. Internal cephalic mould, x4.5, GSC 98999, GSC loc. 90569.

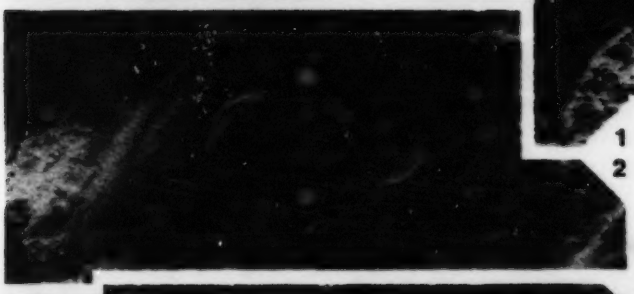

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PLATE 5

Figures 1–5. *Nevadella perfecta* (Walcott, 1913).

1. Internal cephalic mould, x3.9, GSC 99000, GSC loc. 90567.
2. Silicon replica of internal cephalic mould, x3.6, USNM no. 60082, locality 61k.
3. Internal cephalic mould, x2.8, GSC 99001, GSC loc. 90567.
4. Silicon replica of internal mould, x3.5, USNM 443735, locality 61k.
5. Silicon replica of internal mould, x3.0, USNM 443734, locality 61k.

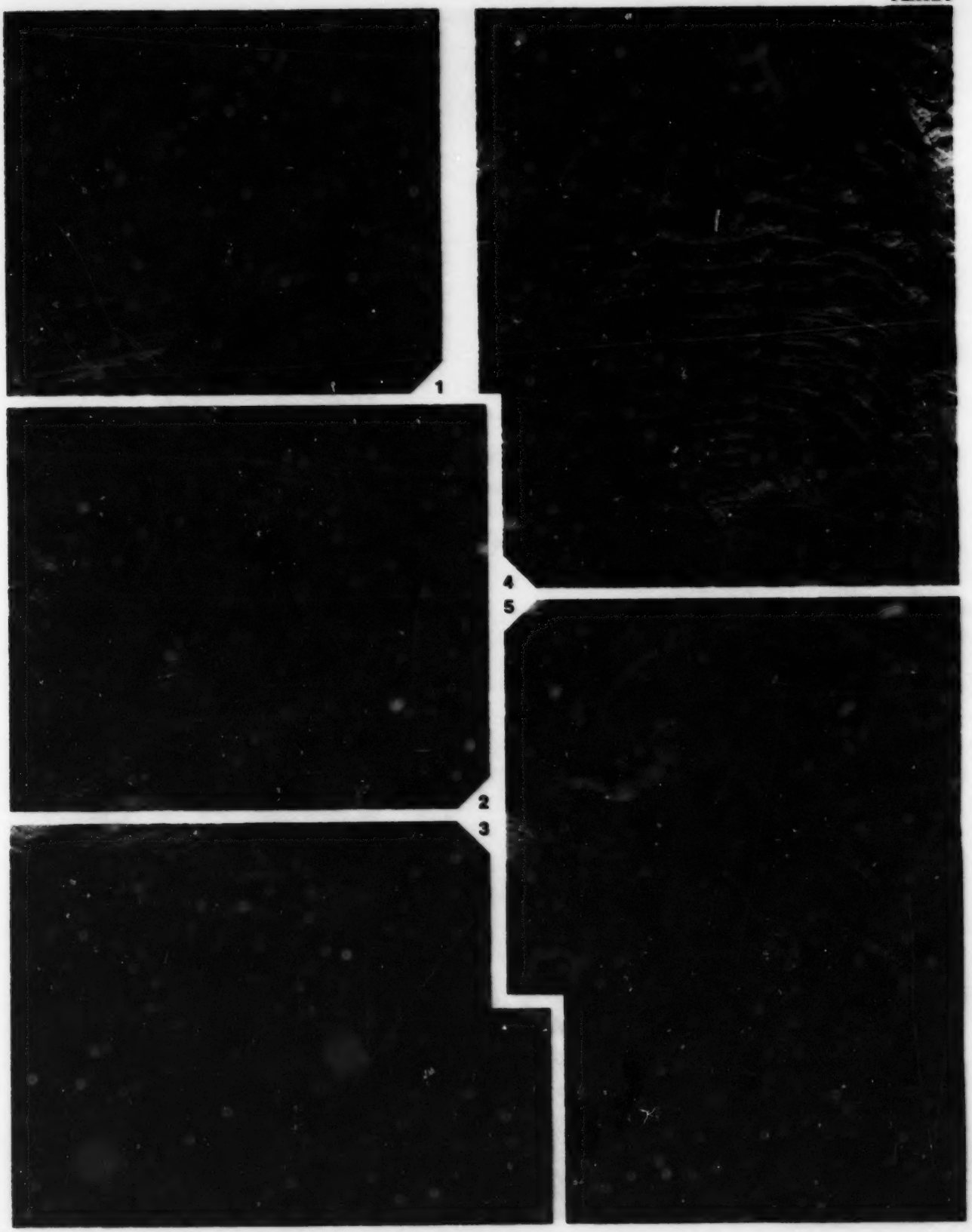
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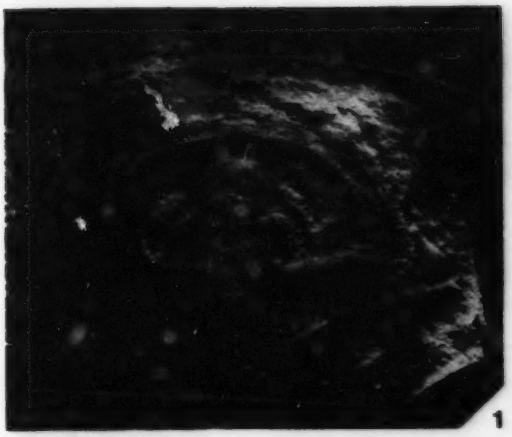
PLATE 6

Figures 1–4. *Olenellus truemani* Walcott, 1913.

1. Latex cast of external cephalic mould, x8.0, GSC 99002, GSC loc. 90572.
2. Internal cephalic mould, x8.0, GSC 99003, GSC loc. 90572.
3. Internal cephalic mould with prothorax attached, x7.4, GSC 99004, GSC loc. 90574.
4. Latex cast of external cephalic mould, x5.5, GSC 99005, GSC loc. 90574.

Figure 5. ?*Gabriellus lanceatus* gen. et sp. nov. Tentatively assigned prothorax, latex cast from external mould, x4.6, USNM 443737, locality 61k.



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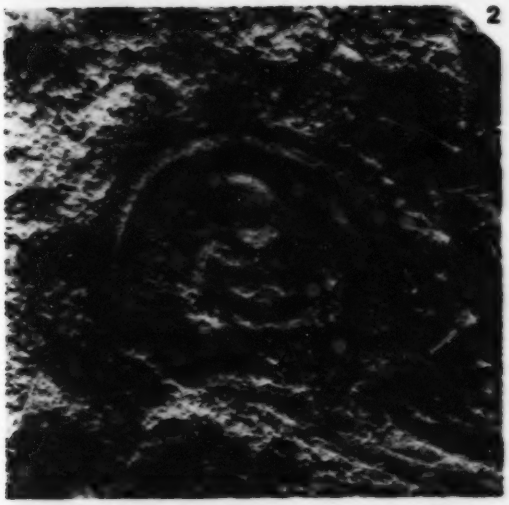

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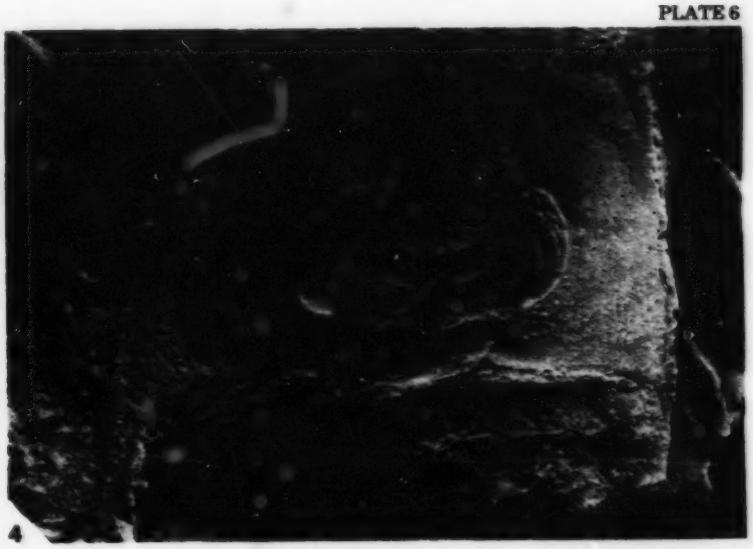

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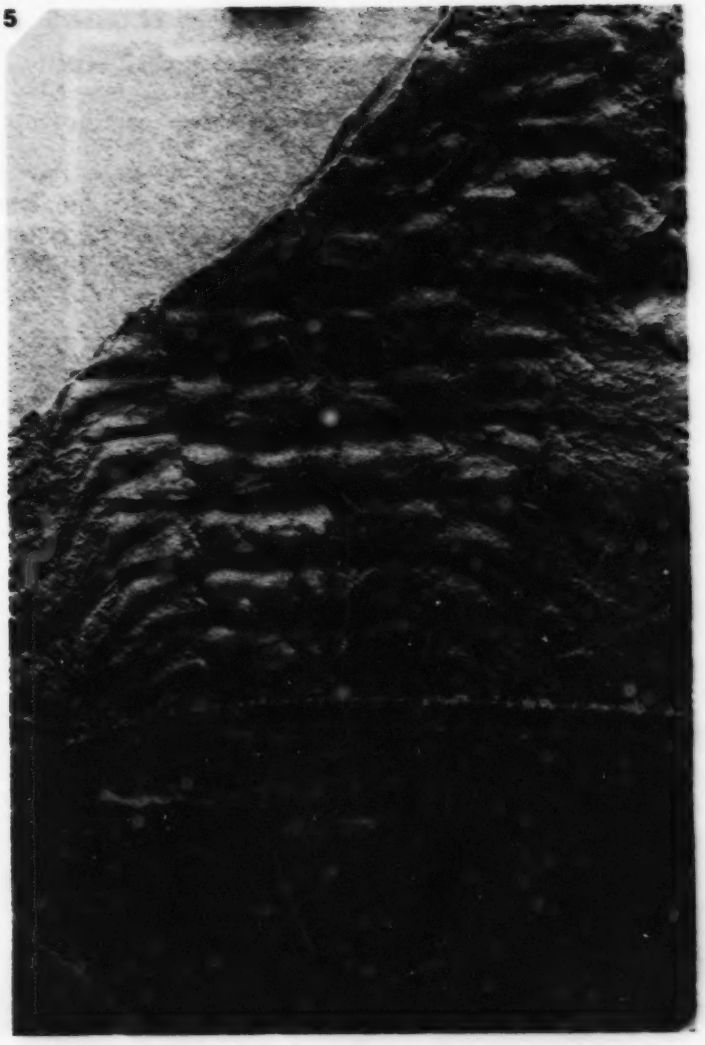

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PLATE 7

Figures 1–6. Internal moulds of *Olenellus truemani* Walcott

1. Two cephala, x5.3, GSC 99006 (upper), GSC 99007 (lower), GSC loc. 90572.
2. Latex cast of external mould of prothorax, x4.7, GSC 99008, GSC loc. 90573.
3. Cephalon, x5.6, GSC 99009, GSC loc. 90573.
4. Hypostome, x14.0, GSC 99010, GSC loc. 90572.
5. Cephalon, x6.2, GSC 99011, GSC loc. 90572.
6. Cephalon, x5.6, GSC 99012, GSC loc. 90573.

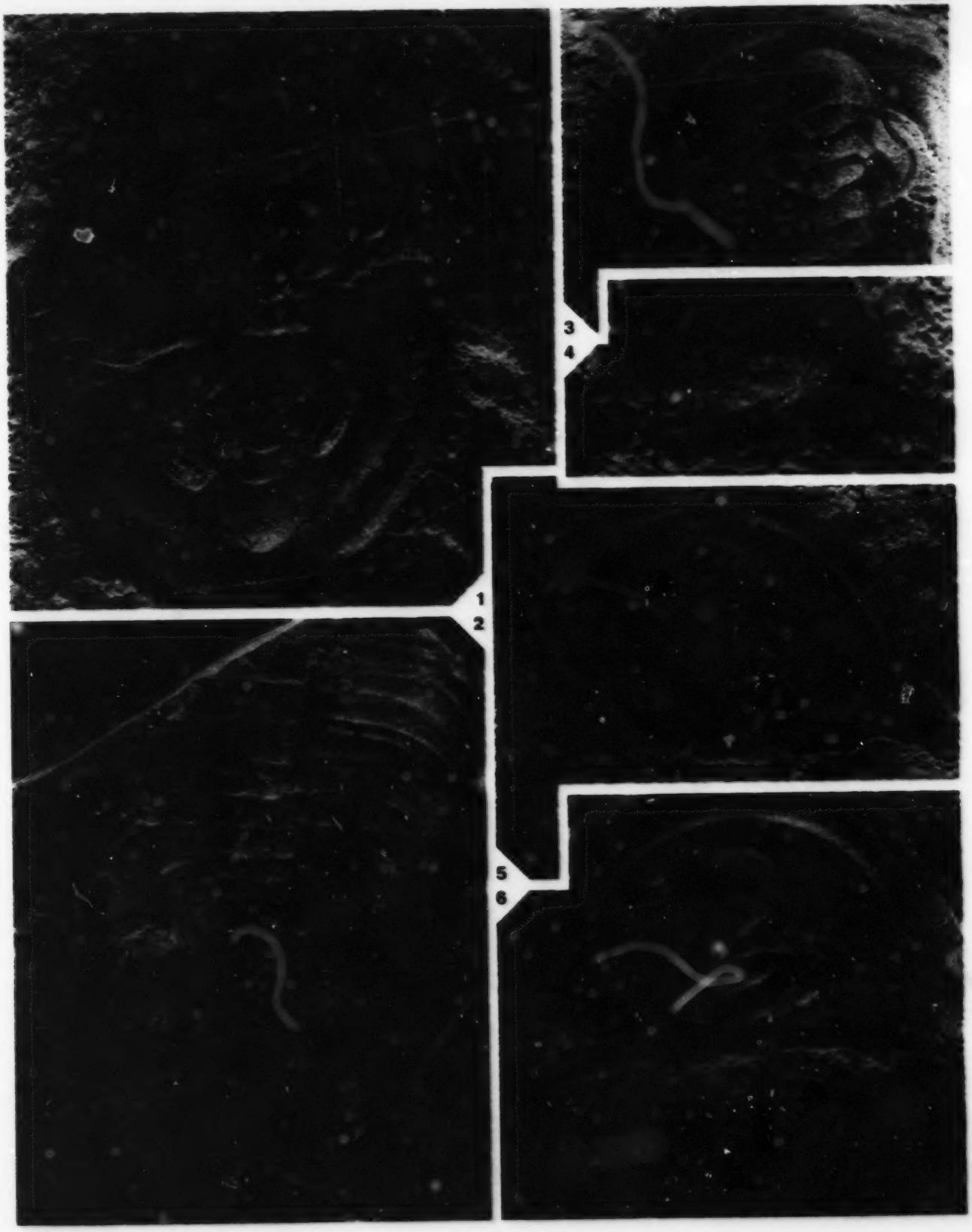
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PLATE 8

Figures 1–7. *Olenellus muralensis* sp. nov., locality 61k, all latex casts of external moulds, except for internal mould in figure 4.

1. Cephalon and prothorax, x5.0, USNM 443738.
2. Cephalon and prothorax, x5.0. USNM 443739.
3. Cephalon and partial prothorax (note arcuate impression of rostral plate at anterior end of cephalon), x3.6, USNM 443740.
4. Cephalon and prothorax, x3.6, USNM 443741.
5. Cephalon and partial prothorax, x3.6, USNM 443742.
6. Cephalon, x2.3, USNM 443743.
7. Enlargement of cephalon in figure 6, x5.6.

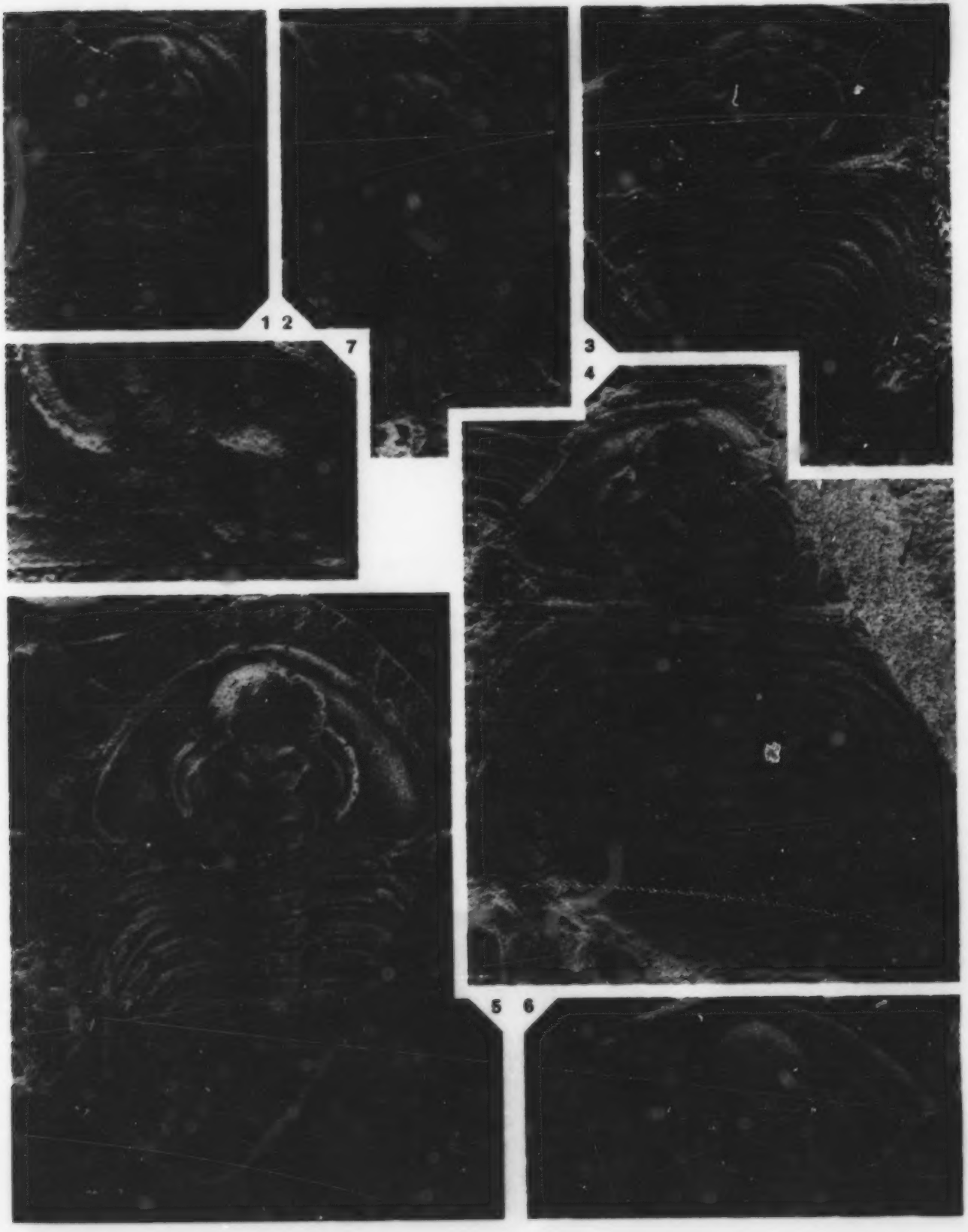
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PLATE 9

Figure 1. *Olenellus muralensis* sp. nov., locality 61k, latex cast of external mould, x2.6, USNM 443744.

Figures 2–5. *Mummaspis occidens* (Walcott, 1913), locality 61k.

2. Internal mould of partial cephalon and prothorax, x4.0, USNM 443745.
3. Internal mould of cephalon, x3.5, USNM 443746.
4. Internal mould of cephalon, x3.5, USNM 443747.
5. Internal mould of hypostome, x10.0, USNM 443748.

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PLATE 10

Figures 1–5. *Mummaspis occidens* (Walcott, 1913), locality 61k.

1. Latex cast of external mould of cephalon and prothorax, x2.8, USNM 443749.
2. Latex cast of cephalon and partial thorax, x2.8, USNM 443750.
3. Internal mould of cephalon, x2.3, USNM 443751.
4. Enlargement of cephalon in figure 3, x6.6.
5. Enlargement of cephalon in figure 3, x4.5.

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PLATE 11

Figures 1–5. *Laudonia amputata* sp. nov., locality 61k.

1. Internal mould of cephalon and partial thorax, x4.0, USNM 443752.
2. Internal mould of cephalon, x1.8, USNM 443753.
3. Enlargement of cephalon in figure 2, x8.1.
4. Mostly exfoliated cephalon and partial thorax, x4.0, USNM 443754.
5. Mostly exfoliated cephalon, x4.0, USNM 443755.

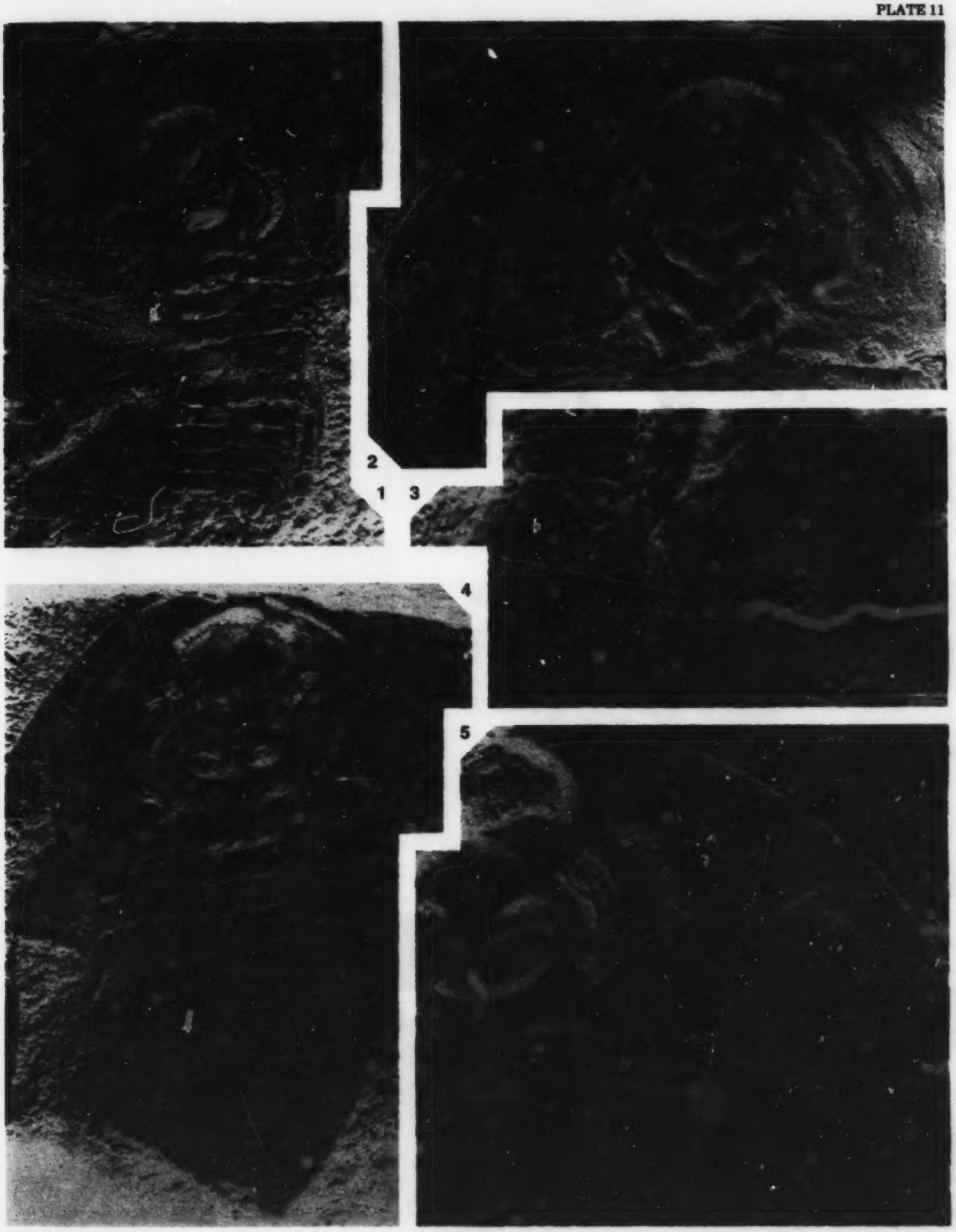
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PLATE 12

Figures 1–3. Latex cast from internal mould of cephalon and partial thorax of *Laudonia amputata* sp. nov., x2.2 (fig. 1), x4.0 (fig. 2), x11.0 (fig. 3), locality 61k, USNM 443756.

Figures 4–8. *Laudonia bispinata* Harrington, locality 61k.

4. Latex cast of cephalic external mould, x3.7, USNM 443757.
5. Latex cast of two cephala from external moulds, x3.7, USNM 443758 (upper), USNM 443759 (lower).
6. Internal mould of cephalon, x3.7, USNM 443760.
7. Internal mould of cephalon, x3.7, USNM 443761.
8. Internal mould of cephalon, x3.4, USNM 443762.

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PLATE 13

Figures 1–8. *Laudonia bispinata* Harrington, locality 61k.

1. Latex cast from mainly external surface of cephalic mould, x1.7, USNM 443763.
2. Internal mould of thorax and partial cephalon, x3.4, USNM 443764.
3. Enlargement of lower thorax and pygidium in figure 2, x15.8.
4. Partial internal mould of cephalon, x3.8, USNM 443765.
5. Enlargement of cephalon in figure 4, x9.1.
6. Enlargement of cephalon in figure 4, x11.0.
7. Enlargement of cephalon in figure 4, x11.0.
8. Latex cast of external mould of cephalon, x2.0, USNM 443766.

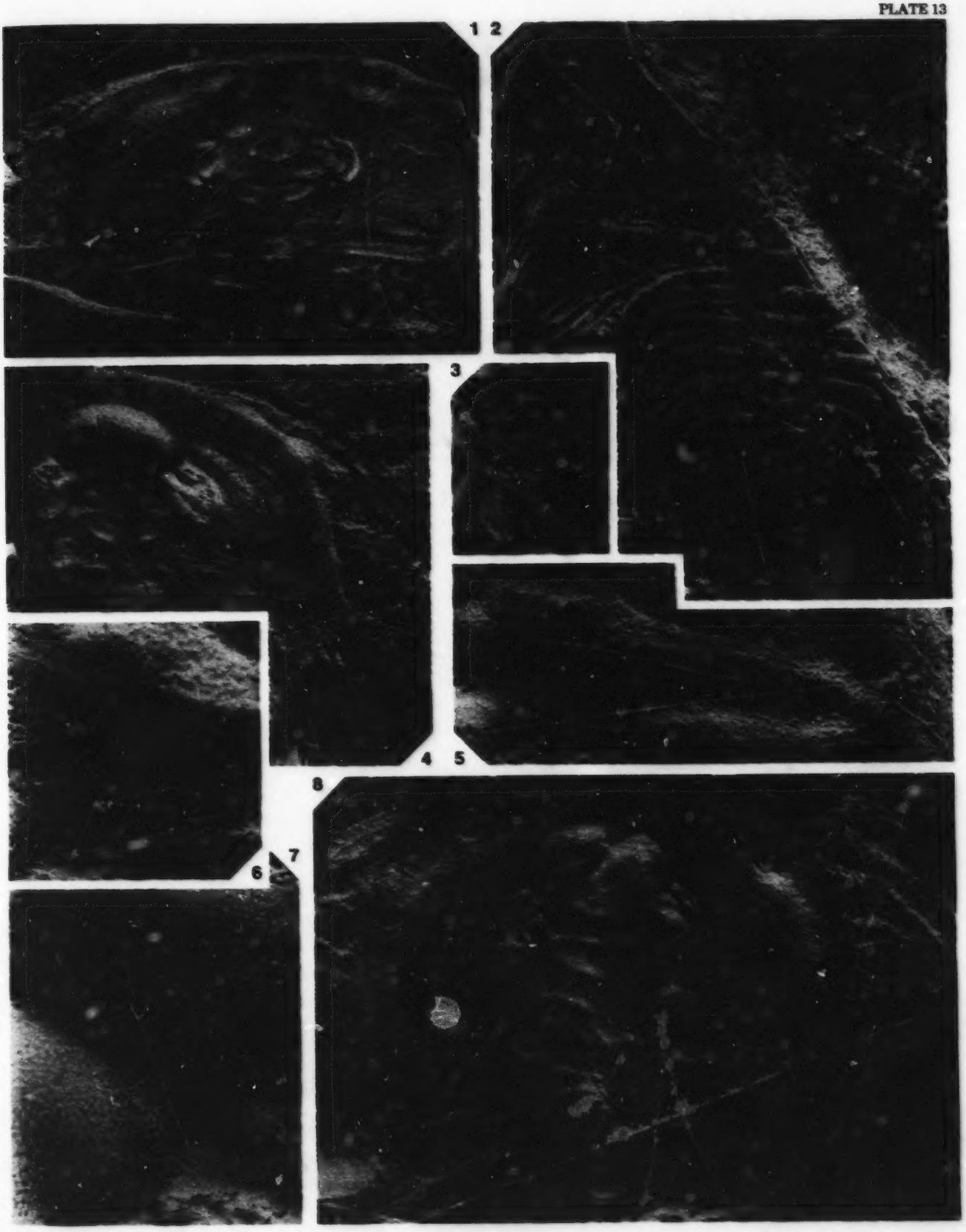
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PLATE 14

Figures 1, 2. *Laudonia bispinata* Harrington, locality 61k, internal mould.

1. Partial cephalon, USNM 443767, and incomplete exoskeleton, USNM 443768, x3.5.
2. Enlargement of pygidium in figure 1, x15.0.

Figures 3–6. *Olenellus truncatooculatus* sp. nov., locality 61k, internal moulds, except for figure 4, which is a latex cast of an external mould.

3. Cephalon, x13.3, USNM 443769.
4. Cephalon, x13.3, USNM 443770.
5. Cephalon, x12.0, USNM 443771.
6. Cephalon, x11.3, USNM 443772.

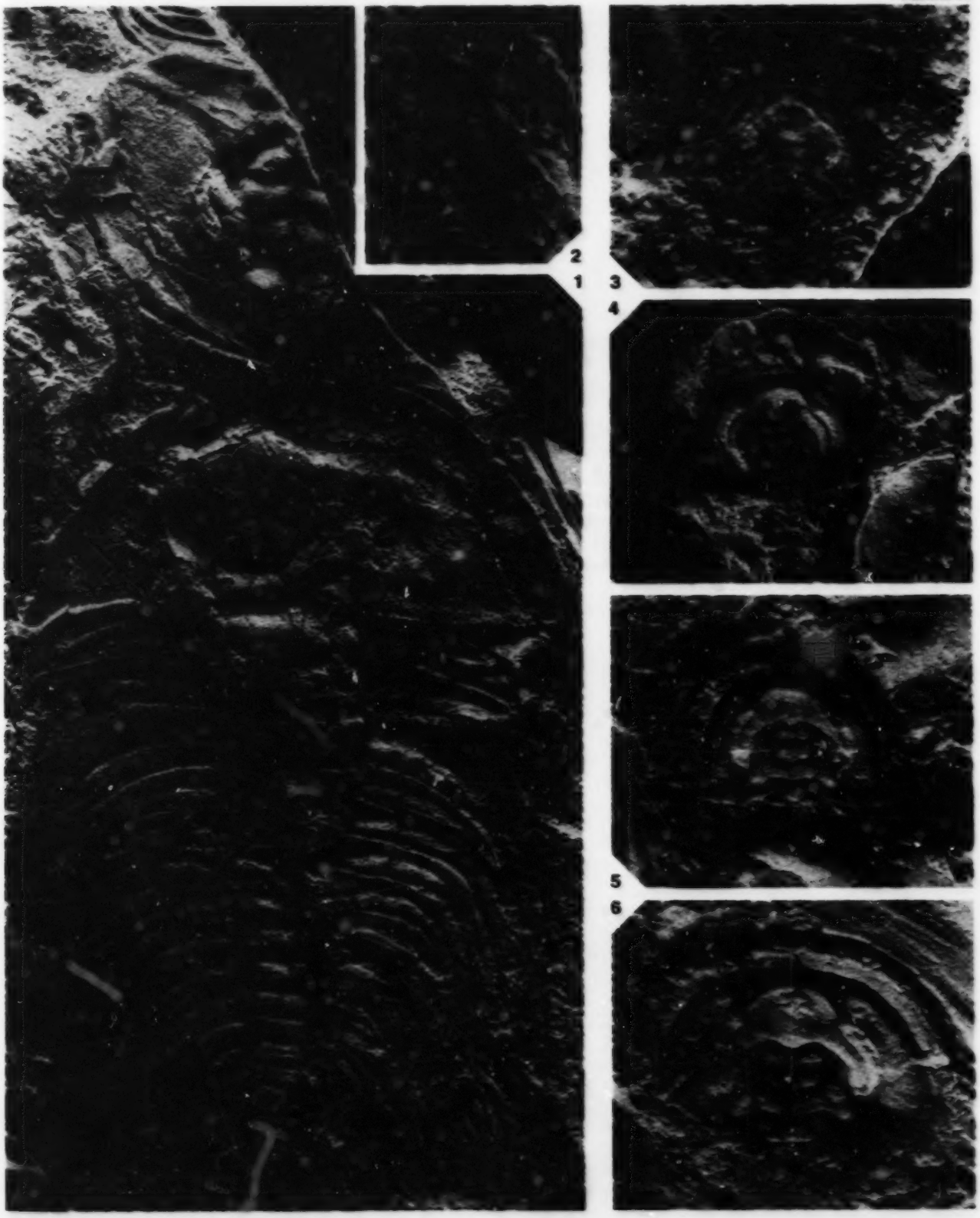
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PLATE 15

Figures 1–9. *Olenellus truncatooculatus* sp. nov., locality 61k, internal moulds, except for figures 3 and 6, which are latex casts of external moulds.

1. Cephalon, x4.1, USNM 443773.
2. Cephalon, x4.7, USNM 443774.
3. Cephalon, x3.7, USNM 443775.
4. Incomplete exoskeleton, x3.8, USNM 443776.
5. Enlargement of lower prothorax, opisthothorax, and pygidium in figure 4, x14.0.
6. Cephalon and prothorax, x3.7, USNM 443777.
7. Cephalon, x4.2, USNM 443778.
8. Cephalon, x4.2, USNM 443779.
9. Enlargement of cephalon in figure 8, x6.8.

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PLATE 16

Figures 1–3. *Olenellus truncatooculatus* sp. nov., locality 61k.

1. Latex cast of an external mould of cephalon and prothorax, x3.9, USNM 443780.
2. Internal mould of cephalon, x3.2, USNM 443781.
3. Internal mould of hypostome, x7.2, USNM 443782.

Figures 4–7. *Mummaspis oblisooculatus* sp. nov., locality 61k, internal moulds.

4. Cephalon, x11.0, USNM 443783.
5. Cephalon, x10.0, USNM 443784.
6. Cephalon, x10.0, USNM 443785.
7. Cephalon, x6.4, USNM 443786.

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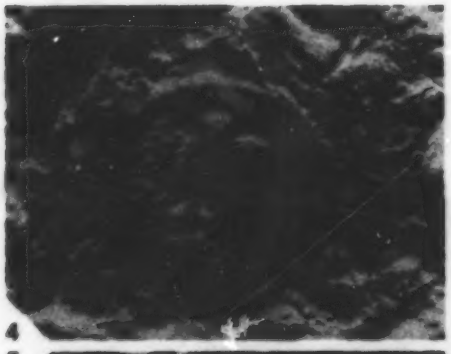

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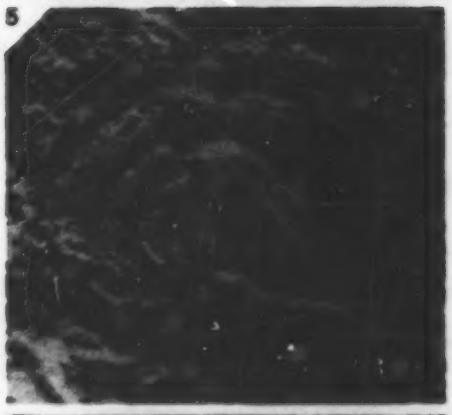

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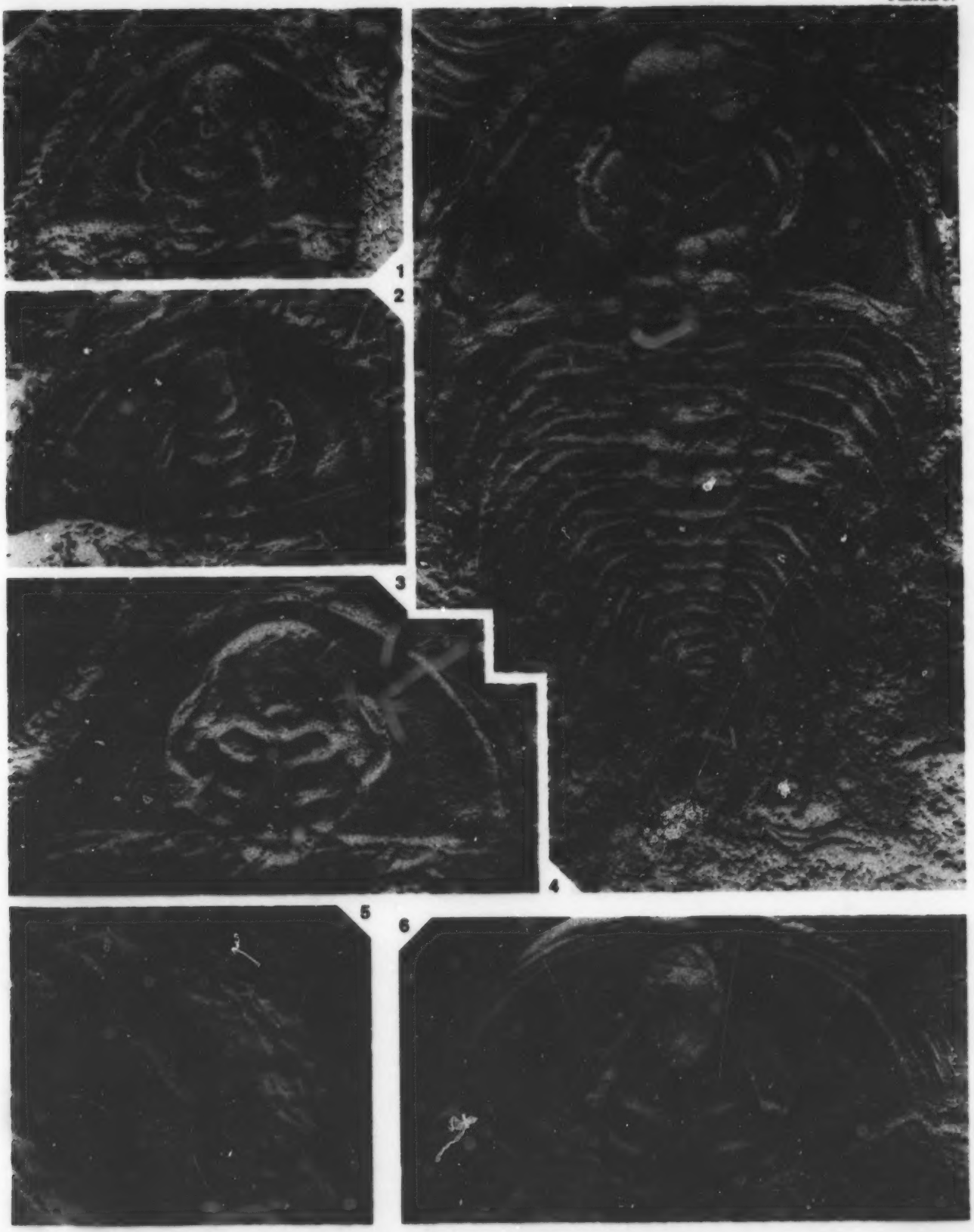
PLATE 17

Figures 1–5. *Mummaspis oblisooculatus* sp. nov., locality 61k, internal moulds (figs. 2, 5) and latex cast from external moulds (figs. 1, 3, 4).

1. Cephalon, x5.0, USNM 443787.
2. Cephalon, x5.0, USNM 443788.
3. Cephalon, x4.0, USNM 443789.
4. Cephalon and prothorax, x3.5, USNM 443790.
5. Hypostome, x14, USNM 443791.

Figure 6. *Gabriellus lanceatus* gen. et sp. nov., cephalic internal mould, x1.9, locality 61k, USNM 443792. (See Plate 6, fig. 5 for tentatively assigned prothorax.)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